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Manual for quality control

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MANUAL FOR QUALITY CONTROL

BY

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PREFACE

Modern trends of industrial development have been directed toward increased output of products with greater precision and uniformity. This necessitates an inspection function that reflects more effective results than ever before. In order to rise to this occasion full use must be made of todays principles and techniques of inspection and quality control.

Industry demanded the use of high precision measuring instruments to aid the inspection function in obtaining effective results. Recently, however, the techniques of Quality Control have become a well-known, useful, tool for the solution of many manufacturing problems. Effective use of these techniques depends on their complete understanding by management, production, inspection, and engineers. Inspection and Quality Control problems are vital management problems as they include organization, human relations, co-ordination with other departments and other elements of the inspection function, such as, purchased material control, process control, sampling plans, quality guarantee, etc.

Many problems will become apparent in the application of control techniques to a new quality program. It is hoped that this Thesis will help relieve some of the problems and possibly prevent others. This Thesis is primarily intended to be a guide for plant executives and shop supervisors for demonstrating the modern techniques of managements newest and most useful tool, Quality Control.

Quality Control can be thought of as an effective system for co-ordinating the quality efforts of the various groups in an organization so as to enable production to continue at the most economical level. Benefits often resulting from Quality Control Programs are improvements in product quality and design, reductions in operating costs and losses, improvements in employee morale, and reduction in production-line bottlenecks. The success of quality control in a plant is dependent on the spirit of "quality-mindedness", which should extend from top management right to the men and women at the work bench.

The quality control approach is to control product quality during the process of manufacturing so as to prevent poor quality rather than to correct the poor quality after the article has been produced. Frequency distributions, control charts, and sampling tables are statistical tools which guide the quality control activities. These statistical tools, however, represent only a part of the over-all administrative quality control pattern.

The actual promotion of an acceptable quality control program is very much dependent on the mutual understanding of the basic principles underlying the new program. An attempt has been made to prepare a systematic approach to the problems of quality control that may be utilized later in the development of a complete quality control program. It must be clearly understood, however, that all quality control programs although alike in structure are somewhat different in detail and require a tailoring to suit the applicable conditions.

To date, use of this newest management tool, Quality Control, has provided insurance for top quality at lowest costs for companies both large or small. No matter what the product may be or how the product is made, the role of quality can best be accomplished by means of an adequate Quality Control Program.

Acknowledgement is made to the following sources for their permission to use specific material and charts.

"Statistical Quality Control" - E. L. Grant,
Copyright 1946, McGraw-Hill Book Company, Inc.

"Quality Control" - A. V. Feigenbaum
Copyright 1951, McGraw-Hill Book Company, Inc.

"Production Handbook" - L. P. Alford and John R. Bangs, editors - Copyright 1944, The Ronald Press Company.

"Cost and Production Handbook" - L. P. Alford, editor
Copyright 1934, The Ronald Press Company.

"Quality Control in Industry" - John G. Rutherford
Copyright 1948, Pitman Publishing Corporation.

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CHAPTER I

HISTORICAL ASPECTS OF INSPECTION

Early Concepts of Inspection

Before the year 1785,[1] there was no apparent need for quality inspection as all tools and parts were made or fitted for individual assemblies. Around this time Le Blanc introduced the idea of making the component parts of the musket so exactly alike that what belonged to one might be used on another. This idea of interchangeability could only be accomplished through greater accuracy in production. Le Blanc, however, was unable to complete his experimentation in interchangeability. About fifteen years later, 1799,[2] Eli Whitney carried interchangeability to a conclusion by producing parts for ten muskets and then by picking out any piece at random from the parts required was able to put the parts together without any adjustment.

To get the accuracy required for interchangeability, the early craftsmen measured their work directly with a scale or calipers. During the Civil War the enormous demands for small arms speeded the development of new manufacturing and inspection methods. Following the Civil War an improved system of gauges was developed. The introduction of Go-No-Go type gauges, Micrometer, Precision Gauge blocks, etc. paved the way for greater precision and

1. Progress in Quality Control - J. M. Juran and R. Wareham - Proceedings of Eight International Management Congress, Stockholm, 1948.

2. Story of Mass Production - Charles Kettering and Allen Orth - General Motors Corp., Detroit, Michigan, 1947.

consequently better interchangeability.

Purpose of Inspection

The art of inspection is actually applying tests, through the use of certain measuring devices, to determine whether or not a part is produced within the specified limits.[3] In other words inspection is the function by which the control of quality is maintained. Although all products are produced with permissable limits of variability, it is the function and purpose of inspection to make certain that all the parts manufactured are within the definite limits.

Development of Modern Inspection

The development of precision tools and precision making machines necessitated greater accuracy in the method of checking and inspection. Today inspection makes use of mechanical devices which give more repeatability and sensitivity than is possible through human means. This progress called for adequate and similar adjustments all along the line in inspection organization.

Shortly after World War I, Dr. Walter A. Shewhart and Harold F. Dodge[4] along with several members of the Bell Telephone Laboratories developed methods by which the mathematical probability theory was applied to production sampling procedures.

3. Cost and Production Handbook - Alford - Ronald Press, New York - 1942

4. Sampling Inspection Tables - Dodge-Romig - John Wiley Sons, Inc., London

Quality Control by statistical methods was first applied in the Western Electric plant about 1924 and immediately there was an improvement in scrap and a reduction in rejects up to fifty percent on some items. This work proved to be the foundation for statistical quality control as it is now used in industry.

Other large companies' adoption of statistical methods for quality control resulted in increase in production, improvement in quality, and reduction in costs. As other manufacturers learned of the advantages resulting from statistical quality control, they too became interested and introduced similar programs. During World War II, the Armed Forces, the dominant consumer, were called upon to accept large lots of materials, for immediate shipments to depots. As manufacturing output expanded, it became increasingly difficult for the government inspectors to duplicate the manufacturers inspection. In order to assure quality products, the Armed Forces insisted that all purchased products should conform to specific sampling plans. Industry had little alternative but comply, thence, statistical methods for quality control came into general use.

Quality Control by statistical methods is so extensively applied in all lines of industry, that everyone who is interested in manufacturing should be interested in the methods of Quality Control.

Concept of Quality Control

Quality Control is usually considered to include two distinct functions:[5]

1. Art of screening and accepting the most desirable parts that will satisfy given standards.

2. Control of process and machines so that parts will be produced within given limits.

The function of screening and accepting is the old time inspection department function. The scientific control of processes and control during production is the latest addition that has aided in changing the function from inspection to that of quality control. This approach of inspection not only becomes the guardian of quality but also aids in the adjustment of policies, designs, and manufacturing methods required to obtain the best results. In controlling processes and machines the quality control department has increased its service to the plant with the main object being to prevent the production of bad work.

5. Quality Control in Industry - John G. Rutherford - Pitman Publishing Corporation, New York - 1948

CHAPTER II

QUALITY CONTROL

Definition of Quality Control

Quality Control is usually defined to include the two distinct functions of inspection and control. The function of inspection covers the art of screening and acceptance sampling as practiced by the inspection department. The function of control (scientific control) of processes and machines during manufacturing is a rather recent development of modern inspection.

The term "Quality Control" is nothing more than a method of measuring the quality of the output against some predetermined standard. The word "quality" usually implies a high level of perfection but does not specify any particular degree of perfection. The word "quality" is no more than a name attached to the characteristics of the manufactured product. In comparing the determined characteristics, the manufactured parts are said to be of good quality if they meet the standard's requirements and of poor quality if they do not meet the standard's requirements.

No two pieces of work are ever exactly alike; they all vary within certain limits. When samples vary beyond the limits, the experts know something is wrong and immediately start looking for the offending operator, machine, or raw material.

Quality Problem

The problem of quality control has been greatly intensified by various characteristics of mass-production techniques. These characteristics include:

1. Subdivision of Labor - The reduction of each job to a single operation.

2. Decrease of Skills - The operators tend to depend too much upon the machines to get the work out.

3. Incentive Payment Plans - Emphasizes more production, stressing quantity rather than quality.

4. Inspection Organizations - Implies lack of responsibility on the part of the workman. That is, the control of quality is emphasized by the addition of more and more inspectors, hence, the workmen tend to develop a feeling that the responsibility for quality rests along with the inspector. "Let him (inspector) worry about it. That is his job."

Compare the attitude of the old artisian with that of the present-day mass-production worker. The artisian, having a part in the final product, felt the direct effect of quality. The present-day worker, being far removed from the finished product, very often has no realization of what the final product is or the part that he actually plays in making that product. In other words the present-day worker does not "get a kick" out of being part of the product. To help solve the quality problem, one of the prime responsibilities of management is to recreate some of that old-time pride in quality work.

Objectives of Quality Control

Lack of competition caused by a sellers market forced many manufacturers to produce greater quantities of products than ever before. It must be understood, however, that anyone can turn out substandard products and sell these products very freely in a sellers market. The future of these companies usually is not too bright. In the final analysis, the consuming public will decide which product has the greatest quality. It is imperative that great concern should be placed on increasing quality, because everyone knows that as competition becomes more keen, the ability to win and hold a market will bring into focus the importance of producing a quality product that is acceptable to the consumer. The consuming public is becoming more and more critical both of price and quality.

Quality Control is a tool of management which can be used to maintain and improve the quality of the product in order to meet competitive standards and reduce the cost of waste. Top management cannot relax for one instant in its attitude toward maintenance of quality standards. This attitude must be reflected down through the entire organization to each employee. It is believed that Statistical Quality Control, the newest management tool, can and is aiding materially not only the maintenance of quality, but the improvement of quality with corresponding decrease in costs.

Benefits of Quality Control

The benefits made possible by the use of quality control in manufacturing are as follows:[6]

1. Reduction of the costs of scrap, rework and adjustment.

2. Reduction in the costs of the factors of production through random assembly, uninterrupted production, and greater utilization of labor and facilities.

3. Reduction in costs of inspection.

4. Improved attainable quality standards, with either higher market values for a given sales volume, or greater volume for a given price.

5. Lower cost designs of products and processes for a given product quality standard.

6. Improved technical knowledge, more reliable engineering data for product development and manufacturing design, and reliable characterization of the attainable performance of processes.

What Management Expects from Quality Control

Management expects a great many benefits from quality control. It looks for better quality, for increased production and lower costs, and for greater customer satisfaction. But at the same time management expects quality control to develop a closer, more satisfying relation-

6. Production Handbook - Pg. 680 - Ronald Press Company New York, 1947

ship between the worker and his job. It expects that through a quality program there will be an increased sense of responsibility and a more conscientious job-attitude on the part of the men and women on the production line as well as all supervision. Management expects the workers to be proud of what they do and beyond any doubt it thinks much could be accomplished by tapping the deep human urge that is in all of us to do a good job. There really are not many people who are happy with just getting by. To achieve quality production it is necessary to get at the root of real quality - Pride of Performance.

The products turned out by an industrial concern are as good or as bad as the workmanship of the people who make up the concern. In spite of the increasing use of machinery, which tends toward greater uniformity of the products, the human element is still the controlling factor. When the human element, that is labor or management, does a poor job then management needs to worry. It is this constant threat of poor workmanship that management expects to be greatly decreased by the proper use of quality control.

Measurement of Quality in the Shop

Measurement of poor workmanship in the shop is the best way top management has of evaluating the quality of a shop. One method of evaluation of quality is determining the percentage of scrap produced by the shop during a certain period. This figure indicates the efficiency of the present shop operations.

Another way to check or measure the quality in the shop is the use of Quality of Conformance Curves. As shown in Figure 1 the basic manufacturing cost, that is raw materials and labor, remains the same whether the part is to specifications or not to specifications. Whenever defective parts are produced, additional costs are involved in the reworking of the parts to meet the proper specifications. Consequently the lower the conformance of quality the greater are the costs of production.

On the other hand, to obtain greater perfection sometimes requires additional costs for control purposes. Here again if the cost of control is out of balance with the conformance of quality required, the costs of production will again be very much greater. There is, however, a optimum point or balance where the greatest conformance is obtained at the lowest total cost.

With past experience and data the optimum balance can be determined and then the relative efficiency of the shop can be determined by checking current data on the formulated curve. If the new total cost is to the left of the optimum balance, the efficiency of quality in the shop is

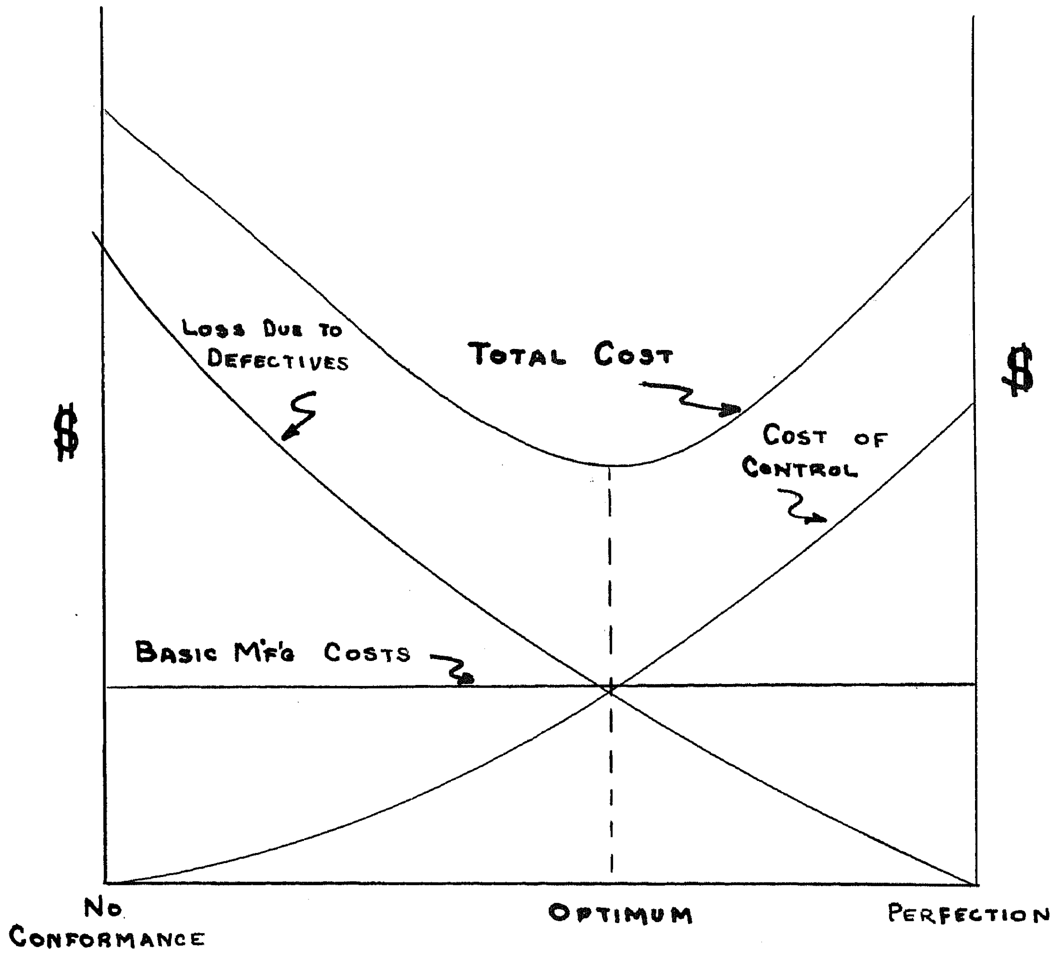


Figure 1 - Quality of Conformance[7]

7. Taken from lecture by J. M. Juran, 1948.

below the determined normal (that is assuming the cost of control is maintained at the level designated by the optimum balance). In like manner if the new total cost is to the right of the optimum balance, then the number of defects would naturally be less and consequently the efficiency of the quality in the shop would be above the determined normal.

Value of Quality

Facts concerning the cost and value of quality are widely scattered throughout the entire organization of the entire plant. Purchasing, Accounting, Service, Marketing, Methods, Inspection, Production, Research, and Design know the facts as to the cost of quality. Advertising, Service, Marketing, Accounting, Inspection, Research, and Design know the facts as to the value of quality. Since no one department knows the value of quality due to the mass of little problems, all the possible sources of information should be pierced and accumulated at one point. How to accumulate all this information at one point is the basic question confronting management. Analysis shows that it cannot be done at the top of the organization but it must be done somewhere at the bottom of the organization.

Relationship Between Quality and Cost

In approaching the problem of quality, one should look at the practical side and should not only proceed with the application of statistical techniques based on theoretical considerations only. In other words, it is necessary for the practical quality control engineer to give due consideration to the many factors which tend to influence the economic side of the picture as well as to the technical factors. Much consideration must be given to those factors that determine the cost of quality as to those factors that determine the benefits to be derived from quality. The quality control engineer is responsible for determining according to his ability that point on the relative scale of quality where added improvements in the process begin to yield less in return economically than the increase in cost required to produce those same refinements. A graphic representation of relative quality is shown in Figure 2.

As indicated in Figure 2 that as the relative quality moves from a minimum to maximum value the cost of quality rises slowly at first and then more sharply as quality approaches perfection, whereas the benefits of quality rise sharply at first and then taper off gradually as a state of perfection is approached. The point where these two curves meet is considered the optimum value on the scale of relative quality. It is this point that should be approached as closely as possible at all times. If one

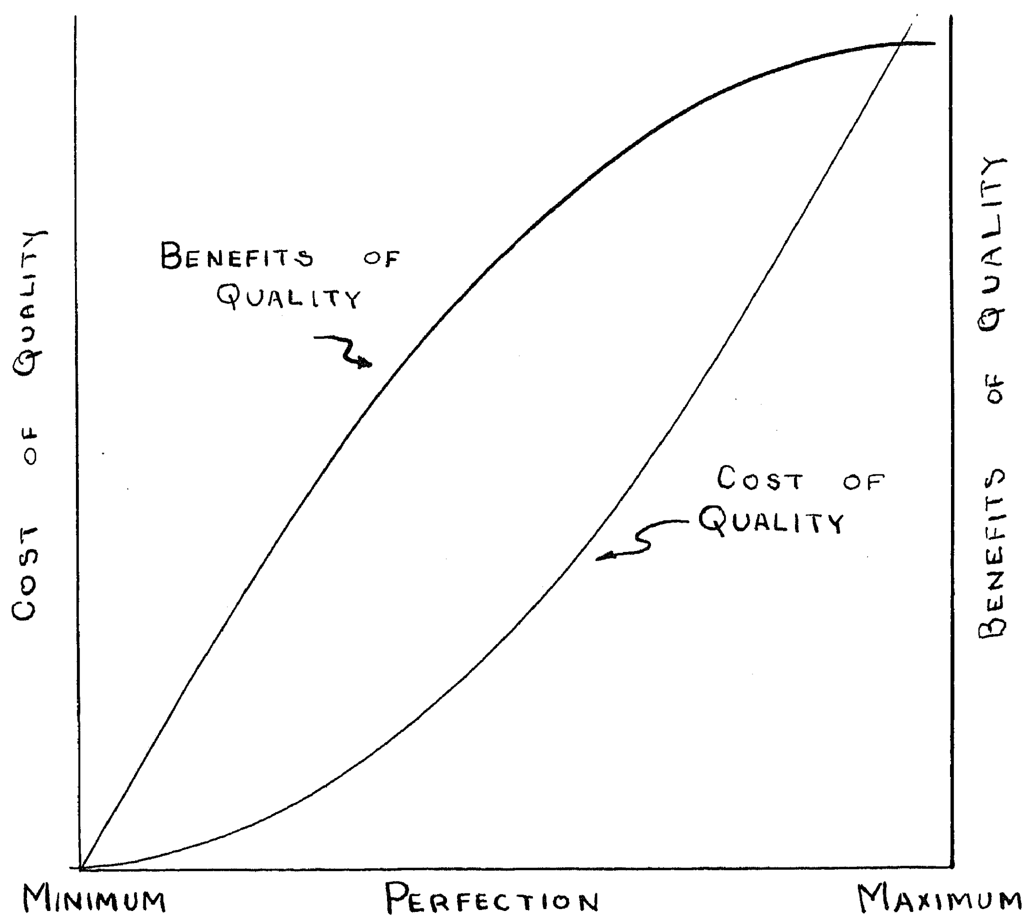


Figure 2 - Relation of Cost and Quality[8]

8. Taken from Course "Industrial Quality Control" - Professor Jaffee, 1950.

could determine this optimum point exactly and schedule operations accordingly, then every cent that was expended in improvement of materials, process, equipment, etc., would be returned in the form of reduced scrap, rework, and other non-essential manufacturing costs, increased customer satisfaction, and improved competitive quality. Hence, a minimum cost of operation and a maximum of customer satisfaction result in an economic balance most satisfactory to all concerned.

Principle of Quality Control

Included in L. P. Alford's generally accepted principles of management are the principles of production inspection and quality control.[9] They are:

1. The quality of manufactured goods is a variable with an upward trend under conditions of competitive manufacture.

2. Control of quality increases output of saleable goods, decreases costs of production and distribution, and makes economic mass production possible.

3. The inspection function in manufacturing (measuring and judging production) for highest efficiency must be independent of, but co-ordinated with, the functions of engineering, production, and sales.

4. The conformance of finished product to its design specifications and standards should be accomplished by avoiding the making of non-conformance material rather than sorting the good from the bad after manufacture is completed.

9. Production Handbook - Alford and Bangs, 1947 - Ronald Press Company page 1390.

Competition dictates to a certain extent the quality level of the goods being manufactured. The average consumer, having a choice of similar products, would undoubtly accept the product of greatest quality. Therefore, whenever a consumers market exists, quality will tend to be at a higher level than when a sellers market exists with no real competition due to the scarcity of the product.

Effective control of the quality function throughout manufacture increases the production of saleable goods by reducing the manufacture of rework, seconds, and scrap materials. Less handling of rework materials and repairs decreases the costs of manufacture and also the costs of distribution by reducing the number of defects returned to the manufacturer for repair or replacement.

The inspection function in most industries is independent of the production function. Present industries have found that greater efficiency in manufacture can be obtained by co-ordinating the functions of Engineering, Production, and Sales with the Quality function rather than making Quality a part of any function.

Quality Control, as used in industry today, aids in the detection of any other possible troubles before the actual manufacture of any non-conformance parts or materials. Control of this nature assures the conformance of the finished product without sorting the good from the bad parts after manufacture.

Advantages of Quality Control

Some of the advantages[10] made possible by the use of quality control to a process are:

a. Greater uniformity of product

b. Larger volume at no increased cost

c. Reduction in wastage

d. Reduction of cost of inspection

e. Detection of trouble

f. Avoidance of trouble

g. Authentic record of the quality of the product

h. Improved Producer-Customer relations

Inspection costs may be reduced by the use of economic sampling inspections instead of attempting to screen out the defective units by 100 per cent inspection. Additional savings in scrap and rework can be realized through the elimination of the assignable causes of rejects. These assignable causes for rejects can be tracked down through the control chart by careful sampling. Control charts not only detect trouble but always provide advance warning of impending troubles long before commonsense would have noticed any change in conditions. Producer-Customer

10. Important Advantages of Statistical Quality Control - Industrial Quality Control - May, 1950 -Vol.VI #6

relations are improved by obtaining greater uniformity of products through control of production processes. Control charts provide one way of obtaining the facts about any particular process. These facts are helpful in aiding design in that it shows an accurate picture of what each process or machine can actually do. Authentic records of past performance on parts and machines enables the proper selection of machines for adequate process control.

Statistical Quality Control, properly applied throughout manufacture, results in more uniform quality at lower cost and at the same time provides more reliable and more useful inspection results than any 100 percent inspection involving judgement or the possibility of human error. A manufacturer who relies entirely on detailed inspections of each unit of product to protect his quality cannot compete successfully, either in respect to uniformity of product quality or in production costs, with the manufacturer who makes full use of statistical quality control practices.

Summary

Quality Control is one of the important objectives of management. Its establishment and administration determine whether the enterprise will be satisfactory and profitable. Management looks toward quality control for greater customer satisfaction through better quality, increased production and lower costs. Co-operation is a key word for success as the value of quality lies in every department in the plant. When dealing with quality control, consideration must be given to the factors which influence the economics as well as the technical aspects of the product. It is for this reason that a certain relationship exists between the benefits of quality and the costs of quality.

Application of a quality control program has many advantages throughout manufacture which eventually results in a more uniform product at lower cost.

CHAPTER III

QUALITY CONTROL TECHNIQUES

Theory of Probability

Before discussing the techniques for quality control, it would be well to investigate some aspects of the Theory of Probability. By applying the laws of probability, the insurance companies can calculate quite accurately the risk involved, and then set their rates accordingly. These insurance rates are determined scientifically through statistical research. The laws of probability make a sound foundation for operation when properly applied whether it is for insurance, playing dice, or for quality control.

In the game of dice, the chance or probability of throwing any definite combination could be summed up as follows. Assuming there is one black die and one white die, the Table, Figure 3, showing all possible combinations would be

						WHITE
2	3	4	5	6	7	1
3	4	5	6	7	8	2
4	5	6	7	8	9	3
5	6	7	8	9	10	4
6	7	8	9	10	11	5
7	8	9	10	11	12	6
1	2	3	4	5	6	

BLACK

Figure 3

Combinations of Two Die[11]

11. Taken from Course "Industrial Quality Control" - Prof. Jaffe, 1950 - Newark College of Engineering

The probability curve for the possible combination in throwing two dice is the bell shaped curve shown in Figure 4.

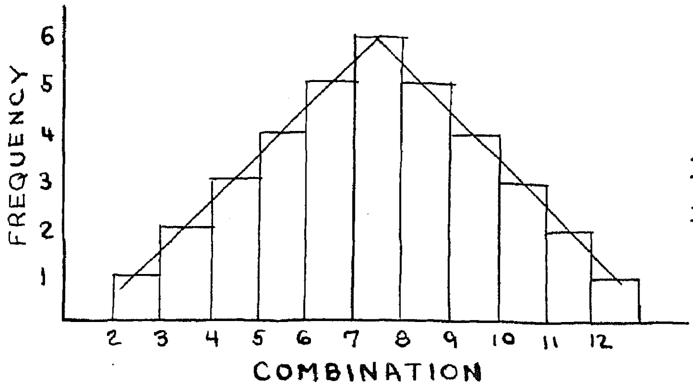


Figure 4

Probability Curve for Throwing two Die[11]

Probability in its mathematical sense has two definitions; the frequency definition[12] and the classical definition. Relative frequency definition of probability -

> "Assume that if a large number of trials be made under the same essential conditions, the ratio of the number of trials in which a certain event happens to the total number of trials will approach a limit as the total number of trials is indefinitely increased. This limit is called the probability that the event shall happen under these conditions."

Classical definition of probability -

> "If an event may happen in a ways and fail to happen in b ways, and all of these ways are mutually exclusive and equally likely to occur, the probability of the event happening is $a/(a + b)$, the ratio of the number of ways favorable to the event to the total number of ways."

12. By permission from Statistical Quality Control, by E. L. Grant. Copyright, 1946. McGraw-Hill Book Company, Inc. (pp. 223-224)

Laws of probability are set up for manufacturing results similar to those used by the insurance companies. From the study of production methods and previous inspection records certain facts can be established which will hold true during normal operations. Experience has taught us that it is necessary to deal with two kinds of variations - the natural variation and the unnatural variation.[13] Since no machine is perfect there are many factors such as: die wear, normal looseness in machine parts, temperature, and any other similar factors that may cause the product being produced to vary slightly from the exact dimension desired. Products with this variation, however, would be within the tolerances required by the specification.

On the other hand, if there was too much looseness in the machine parts, too great a temperature difference, die wear or breakdown, or some other unnatural factor, the product would vary beyond the tolerance range. Hence, the causes which can be discovered and corrected are known as unnatural variations.

Parts produced always vary in size according to the law of probability, provided the operation involved is only affected by the so-called natural causes. When natural causes of variation only are present, the probability curve always assumes a bell shape. (See Figure #5)

13. Quality Control - A. V. Feigenbaum - McGraw -Hill Book Company, New York - 1951

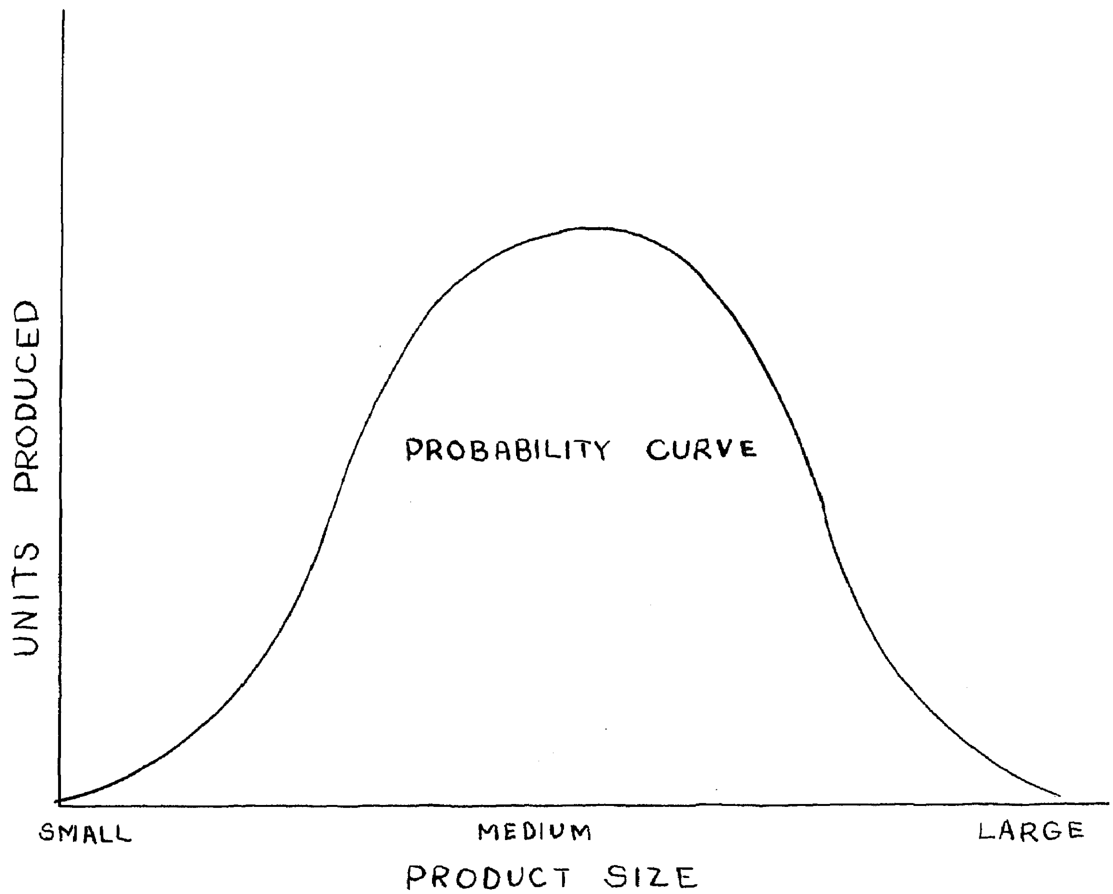


Figure 5 - Probability Curve for Production.

Frequency Distribution Charts

Since variations seem inevitable and desirable in all manufacturing processes, it follows that it is necessary to acquire some rather simple methods of describing these patterns of variation. The statistician has aided with the development of a method involving the use of a frequency distribution. A frequency distribution is the arrangement of a set of observations into class intervals showing the frequency of occurances of a given quality characteristic.

An organized check sheet showing the pattern of variation of a process can be conveniently assembled by counting the frequencies of the different observations of that process and arranging them into their respective class intervals. The size of the class intervals is somewhat dependent upon the number of values to be included in the distribution. The range of the class intervals, that is, the difference between the highest and lowest values of the interval is determined by the number of class intervals desired and also the precision of measurement. Fewer class intervals are used when a limited number of values are included and a larger number when the distribution is to be compiled from many values. The most efficient number of class intervals usually lies between ten and twenty groups.[14] Statisticians using their rough working rule aim to have approximately twenty class

14. Statistical Quality Control - E. L. Grant - McGraw-Hill Book Company - New York 1946

intervals. Another rule of thumb method that is used for determining the number of class intervals can be given by

$$\text{Number of Intervals} = 5 \log_{10} N$$

where N is the total number of readings.
The interval width can be determined by

$$\text{Interval width} = \frac{5 \log_{10} N}{R}$$

where N is the total number of readings R is the Range of N readings.

In order to prevent some of the readings falling at the cell boundaries, the class intervals should never overlap. One method is to set the class interval limits halfway between two possible readings. Another method and general rule is to set the class interval in units of one more than the last significant figure of the data. Whenever possible the class intervals should be of a uniform size. Although there are a number of methods of setting limits, their use is dependent on the nature and form in which the data is reported or collected.

In preparing the check sheet to determine the frequency distribution of some raw data, the class interval groups should be determined and then placed in a column with the lowest class interval at the top and the rest of the class intervals following according to size. The data values can be recorded on the check sheet by checking once next to the class interval into which it falls.

The first step in obtaining a frequency distribution curve is the actual recording of the dimensions being checked. This is usually accomplished by having the inspector record the measurements in table form, (Table 1). Nothing is actually revealed by this table as it represents nothing but a lot of figures. Some valuable information can be obtained by tabulating the readings (Figure 6) into class intervals and then noting the resulting shape of the distribution.

A frequency distribution may be presented graphically by means of a frequency polygon or a histogram. Basically both methods of presentation are alike as they tell exactly the same story. The histogram is made by constructing rectangles using as the width the size of the class interval and as the height the frequency in each class interval. The resulting graphic representation is known as the rectangular frequency polygon or histogram, (Figure 7). In preparing a frequency polygon, the frequency is plotted at the midpoint of each respective class interval. By connecting all the plotted points a frequency polygon is formed, (Figure 8).

.6633	.6614	.6643	.6638	.6647	.6606	.6641	.6602	.6625
.6617	.6606	.6663	.6619	.6674	.6615	.6621	.6574	.6697
.6624	.6642	.6646	.6620	.6652	.6643	.6634	.6627	.6674
.6611	.6635	.6642	.6611	.6621	.6613	.6613	.6613	.6634
.6636	.6621	.6641	.6663	.6645	.6656	.6594	.6677	.6671
.6624	.6640	.6697	.6648	.6622	.6700	.6653	.6616	.6694
.6634	.6689	.6646	.6657	.6621	.6629	.6623	.6649	.6626
.6634	.6646	.6604	.6634	.6620	.6637	.6631	.6641	.6637
.6663	.6650	.6626	.6636	.6644	.6575	.6613	.6625	.6665
.6660	.6627	.6673	.6580	.6633	.6605	.6642	.6656	.6649
.6658	.6654	.6667	.6630	.6613	.6600	.6653	.6663	.6643
.6663	.6643	.6665	.6639	.6628	.6654	.6641	.6647	.6662
.6673	.6667	.6624	.6631	.6612	.6592	.6655	.6639	.6655
.6667	.6661	.6662	.6636	.6642	.6575	.6586	.6643	.6621
.6643	.6637	.6630	.6582	.6605	.6610	.6702	.6680	.6597
.6641	.6652	.6676	.6633	.6616	.6650	.6645	.6652	.6619
.6671	.6661	.6682	.6681	.6590	.6651	.6595	.6612	
.6632	.6672	.6659	.6688	.6601	.6626	.6660	.6662	
.6682	.6658	.6653	.6649	.6591	.6650	.6603	.6645	
.6685	.6668	.6655	.6682	.6627	.6653	.6676	.6646	

Table 1. - Check Sheet. Measuring the O. D. of an Automatic Barrel used on a Stamping Machine.

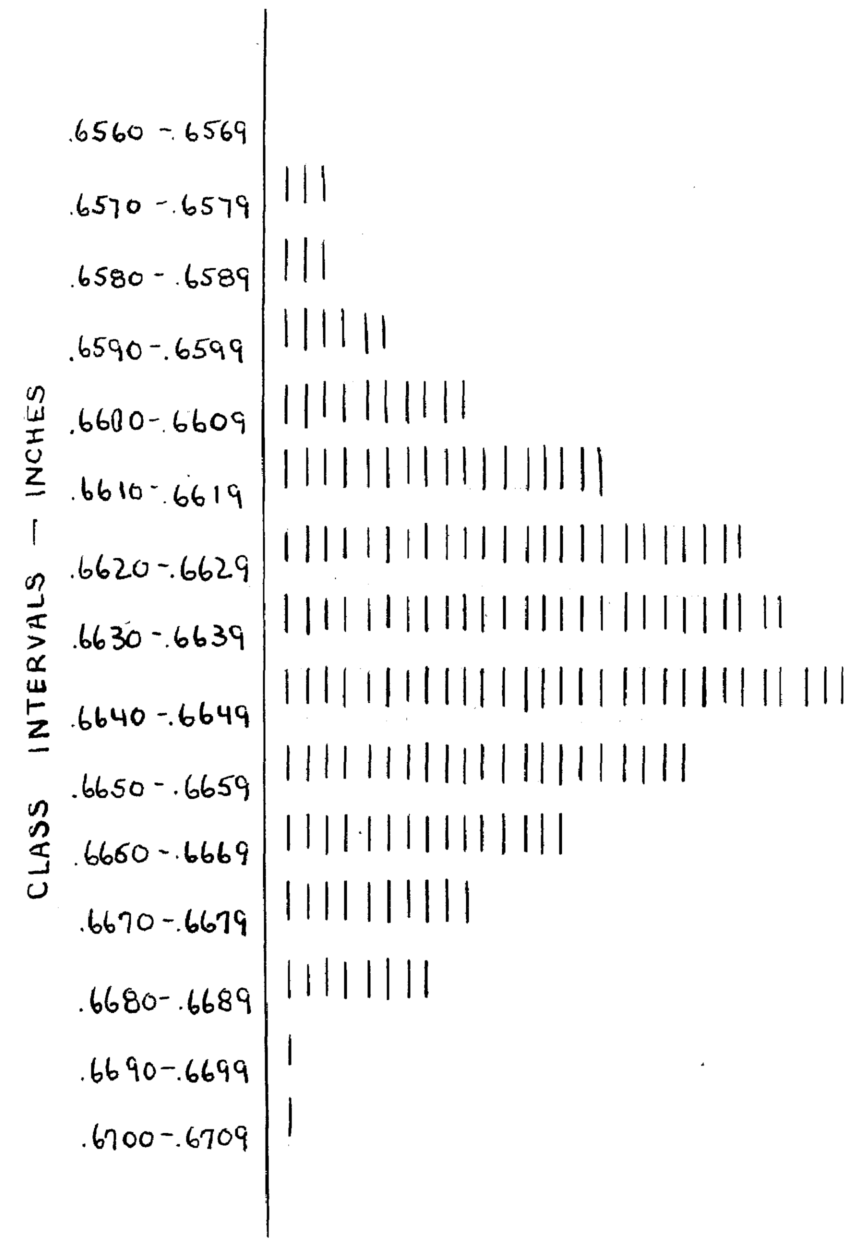


Figure 6 - Check Sheet to Determine Frequency Distribution.

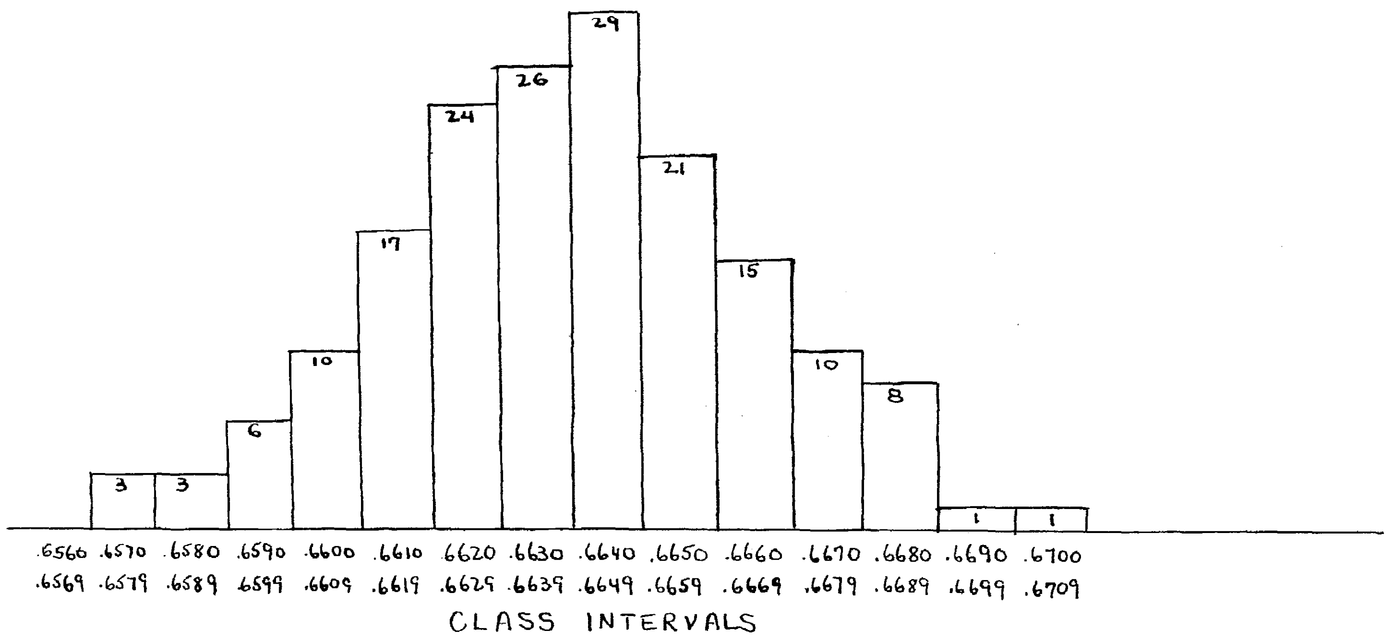


Figure 7 - Histogram - Rectangular Frequency Polygon

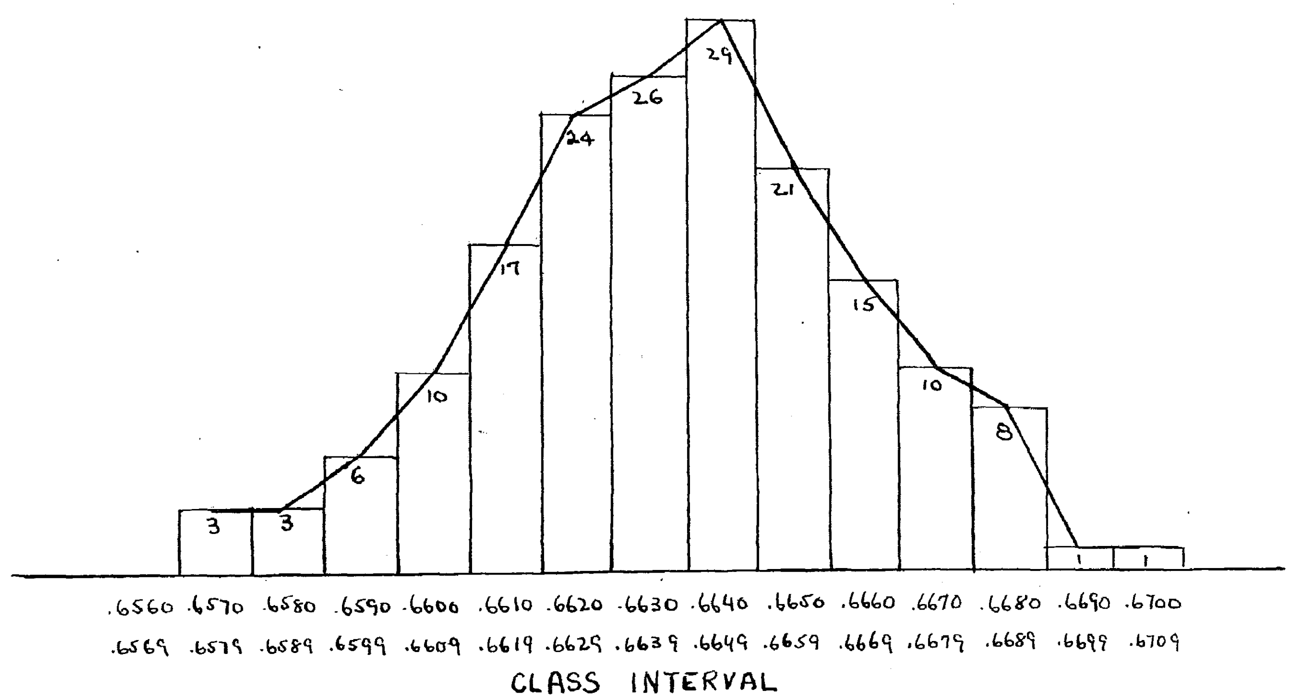


Figure 8 - Frequency Polygon

The usual types of distributions are known as the symmetrical distribution and skewed distribution. One of the best examples of a symmetrical distribution is the normal curve (Figure 9). The skewed distribution which is characteristic of most frequency distributions, extends further in one direction than in the other, hence, there is a lack of symmetry. A distribution skewed to the right is caused by higher values which tend to distort the curve toward the right, (Figure 10). The negative or left skewed distribution is not as common as the right skewed type and is caused by extreme low values which tend to distort the curve toward the left, (Figure 11). Another possible distribution (but not common) is the bimodal, a two peak frequency distribution, (Figure 12), which is possibly caused by the use of two sets of tools, two independent set-ups with the same tools, or a change in the material or process.

The shape of the frequency distribution usually represents the process condition. Distributions, which closely approximate the normal curve, represent processes where only natural variations exist. Skewed or bimodal frequency distributions represent temporary process conditions where unnatural variations exist. These skewed curves act as a guide for detecting the unusual or unnatural variations which must be investigated before

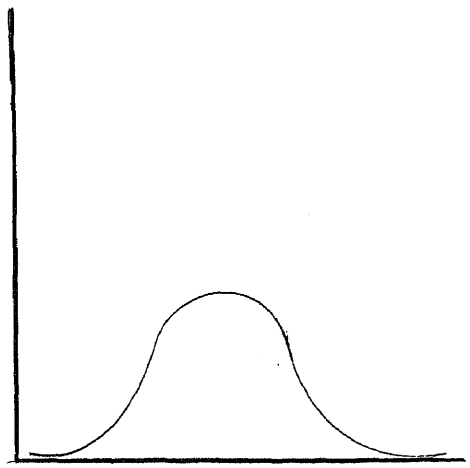


Figure 9 - Normal Curve

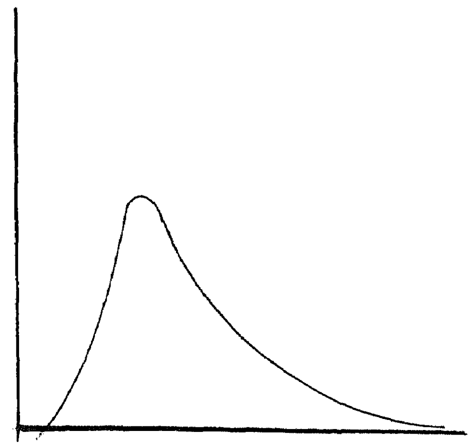


Figure 10 - Right Skewed

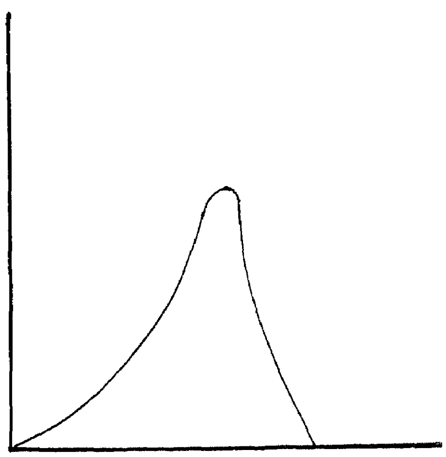


Figure 11 - Left Skewed

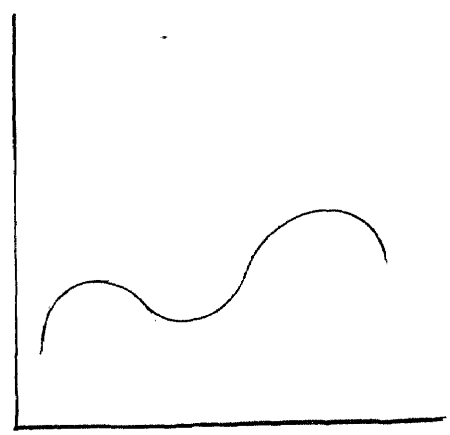


Figure 12 - Bimodal Curve

adjustments or corrections can be made to the machine, tools, or process.

Acceptance Sampling Attributes

The attribute chart,[15] a class of Shewhart Control Charts, must be used to study certain types of quality characteristics, and it may be used for almost any quality characteristic. Any inspection procedure that merely counts the number of appearances of a given quality characteristic without undertaking to measure the characteristic directly is an attribute test, and the data collected by such inspections lead to attribute charts.

Any test which uses go-no-go gauging equipment is an attribute test because no degree of variation is measured. It only gives a "yes" or "no" answer. Likewise, all visual inspection tests are attribute tests. Situations arise where either attribute or measurement charts could be used, depending on the kind of information wanted and the nature of the inspection test. Generally, attribute charts are simpler and less expensive to maintain than are measurement charts. The attribute charts are more flexible in that several different characteristics can be covered by the use of a single chart, whereas each measured characteristic requires its own $\bar{x}$ and $\bar{R}$ chart. In exchange for the advantages, there is a loss of sensitivity when an attribute chart is used in place of a measurement

15. Statistical Quality Control - E. L. Grant - McGraw-Hill Book Company New York - 1946

chart, because an attribute chart cannot provide the detailed information about a characteristic that is available in a $\bar{x}$ and $\bar{R}$ chart.

The best known of the attribute charts are: (1) "fraction defective", or "p" charts (2) "number defective", or "np" charts.

Before a "p" chart[16] can be prepared certain essential information is required.

1. Sample identification by number and time.
2. Number of units inspected in each sample.
3. Number of units in each sample found to be defective for any reason.
4. The ratio of number defective to number inspected or fraction defective.

A typical "p" chart is shown in Figure 14.

On the chart the values for "p", the fraction defective, are plotted as a function of time. The horizontal line labled "p" is the line representing the average value for the fraction defective during an initial period of twenty or twenty-five samples. This line is extended to aid in the evaluating of each future value of "p" as it is obtained and plotted.

The question of sample size for "p" chart work is of great importance. In selecting a sample size, it should

16. "P" Charts for Quality Control - Libedeff and Goode - Factory Management and Maintenance, Vol. 104 #9 ,Sept. 1949

be chosen in some relation to the expected average quality level. Thus, if the quality level is as good as one percent defective on the average, a sample size of at least one hundred is necessary to give any defectives a reasonable chance to show up in the samples. On the other hand, if the quality level is as bad as twenty-five percent defective, useful information may be obtained with samples as low as ten. For a "p" chart to be effective, samples should be expected to show defectives in proportion to the number in the lot, or production quantity from which the sample was drawn.

The key to "p" charts and the feature that makes them of great value are the lines known as "control lines". These are the lines that indicate the range within which the figure for fraction defective of a subgroup may fall while the process is under control and operating in its normal manner. If the value for "p" falls above the upper limit line, it is an indication that some new and important defect-producing cause (unnatural variation) has entered the operation, and that attempts at corrective action are in order. Likewise, a value below the lower line indicates a significant improvement in the process or in some cases, a substantial lowering of inspection standards.

The following is a method for constructing and setting the control limits of a "p" chart. Referring to the Control

Chart Data Sheet, Figure 13, the fraction defective, "p", may be defined by

$$\text{"p"} = \frac{\text{number of defectives found in the subgroup inspected}}{\text{total number of units in the subgroup inspected}}$$

The control chart, Figure 14, shows two scales; the horizontal scale, representing the sample number or identification, and the vertical scale, representing the fraction defective or "p" value. The center line (average fraction defective, $\bar{p}$), is usually taken from past experience and periodically change as improvements are made in process capability. Average fraction defective, $\bar{p}$, may be defined by

$$\bar{p} = \frac{\text{total number of defectives found in all subgroups}}{\text{total number of units in all subgroups inspected}}$$

The control limits for the "p" chart are calculated and then placed at the $3\sigma_p$ limits from the center line $\bar{p}$. Points on the "p" chart may vary within the control limits by chance only, but points outside the control limits justifies the contention that some unnatural cause or causes are present within the process.

Since the subgroup or sample size varies for each group inspected, the upper and lower control limits (U C L p and L C L p) must be calculated for each different subgroup size used. The values for the control limits may be calculated as follows:

Part Name: End Plate　　　　Part No. 321067

Operation: Welding　　　　Inspector: G.C.

Date	Sample No.	(n) Amount Insp.	(np) Number Defects	p(%) Fraction Defective
1/6	1	250	8	3.2
1/7	2	200	6	3.0
1/8	3	200	9	4.5
1/9	4	300	9	3.0
1/10	5	350	11	3.1
1/13	6	200	8	4.0
1/14	7	300	12	4.0
1/15	8	350	14	4.0
1/16	9	350	12	3.4
1/17	10	400	16	4.0
1/20	11	400	26	6.5
1/21	12	300	15	5.0
1/22	13	350	12	3.4
1/23	14	300	11	3.7
1/24	15	300	14	4.6
1/27	16	400	12	3.0
1/28	17	200	10	5.0
1/29	18	200	9	4.5
1/30	19	300	12	4.0
1/31	20	350	14	4.0

Figure 13 - Control Chart Data Sheet.

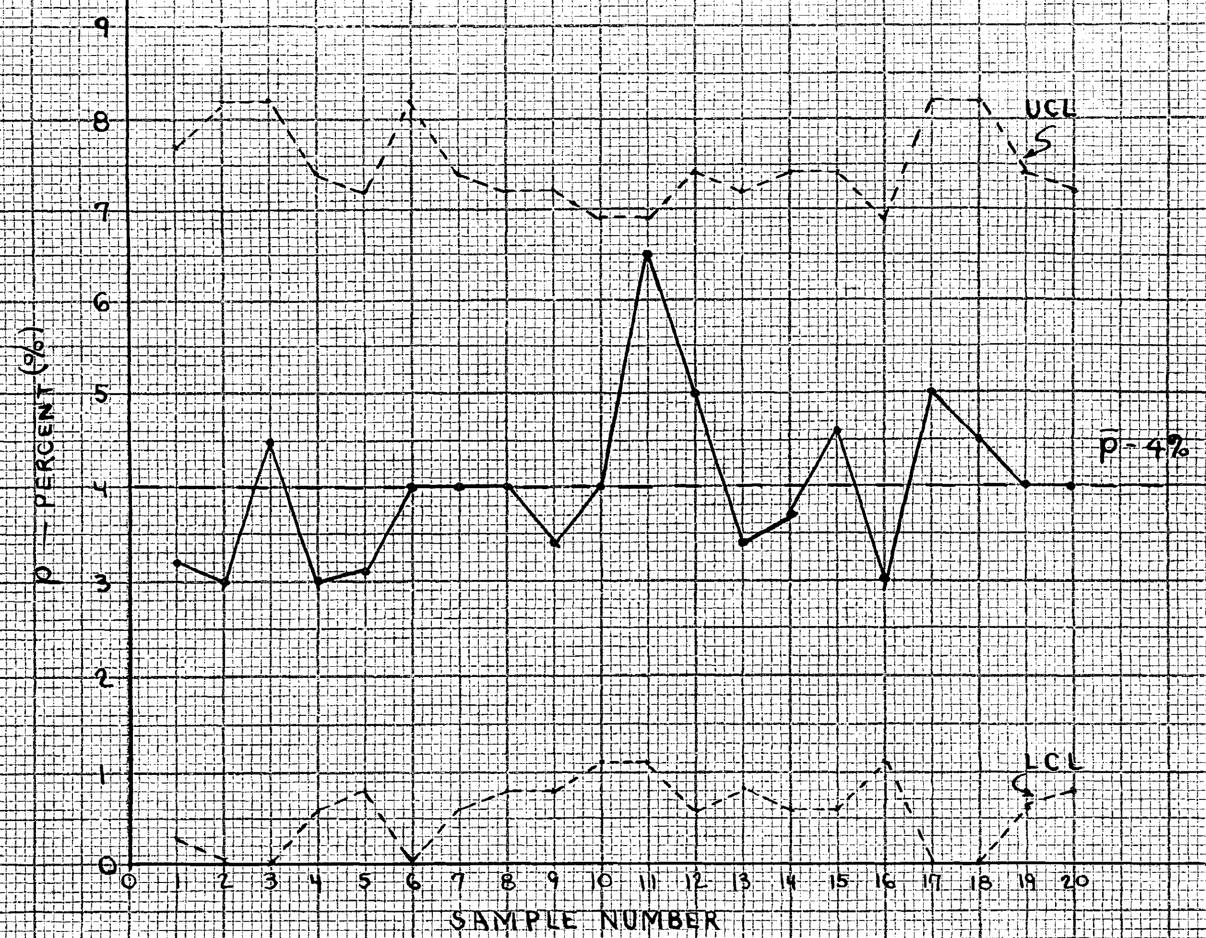


Figure 14 - "p" Chart - (Welding Operation - End Plate - 321067)

$$U\,C\,L_p = \bar{p} + \frac{3\ \ \bar{p}\,(1-\bar{p})}{n}$$

$$L\,C\,L_p = \bar{p} - \frac{3\ \ \bar{p}\,(1-\bar{p})}{n}$$

where $\bar{p}$ is the average fraction defective, n is the subgroup size.

Using the data from the data sheet, Figure 13,

$$\bar{p} = .04 \text{ (past experience)}$$
$$\text{when } n = 250$$

$$U\,C\,L_p = .04 + \frac{3\ \ .04\,(1-.04)}{250}$$

$$U\,C\,L_p = .077 \text{ or } 7.7\%$$

$$L\,C\,L_p = .04 - \frac{3\ \ .04\,(1-.04)}{250}$$

$$L\,C\,L_p = .003 \text{ or } 0.3\%$$

Similarly for the other subgroup sizes

$\bar{p}$	n	$U\,C\,L_p$	$L\,C\,L_p$
.04	200	8.2	0
.04	250	7.7	0.3
.04	300	7.4	0.6
.04	350	7.2	0.8
.04	400	6.9	1.1

The values for the $U\,C\,L_p$ and $L\,C\,L_p$ are plotted on the control chart along with the individual value of "p" for each subgroup inspected. Analysis of the Control Chart, Figure 14, shows the welding process to be in control.

Whenever the inspection procedure can be designed so that the subgroup size remains constant from sample to sample, It is only necessary to enter on the data sheet the number defective found in each sample. Hence, the calculation of the ratio "p" for each sample is eliminated. The control chart made by using this information or data is known as the "np" chart. This chart is simply a special adaptation of a "p" chart. The variable plotted on this chart is the number defective demoted by "np", so the vertical axis is scaled accordingly rather than as a percentage figure. In figure 16, the center line, "np", denotes the "average number defective" per sample.

The following is a method for constructing and setting the control limits on a "np" chart. Referring to Figure 15, Control Chart Data Sheet, it can be seen that the inspection subgroup size is held constant from sample to sample. The variable plotted on the control chart, Figure 16, is the number defective, denoted by "np". The center line (average number defective) is taken from past experience and may be defined by

$$n\bar{p} = \frac{\text{total number of defects found in all subgroups inspected}}{\text{total number of units in all subgroups inspected}}$$

Calculations of the control limits follow the same pattern as described for a "p" chart. Since the subgroup size is constant, only one set of control limits will be required.

$$U\ C\ L_{np} = n\bar{p} + \underline{3 \quad n\bar{p}\ (1-\bar{p})}$$

$$L\ C\ L_{np} = n\bar{p} - 3 \quad n\bar{p}\ (1-\bar{p})$$

Referring to Figure 15 -

$n = 400$ and $\bar{p}$ (past experience) = .04

then

$$U\ C\ L_{np} = 400\ (.04) + 3 \quad 400\ (.04)\ (1-.04)$$

$$U\ C\ L_{np} = 27.7$$

and

$$L\ C\ L_{n\bar{p}} = 400\ (.04) - 3 \quad 400\ (.04)\ (1-.04)$$

$$L\ C\ L_{n\bar{p}} = 4.3$$

PART NAME - END PLATE

PART NO. 321067

OPERATION - WELDING

INSPECTOR - YC.

DATE	SAMPLE NO.	AMOUNT INSP.	No. OF DEFECTS
2-3	1	400	16
2-4	2	400	21
2-5	3	400	26
2-6	4	400	14
2-7	5	400	29
2-10	6	400	17
2-11	7	400	20
2-12	8	400	17
2-13	9	400	12
2-14	10	400	20

Figure 15 - Control Chart Data Sheet

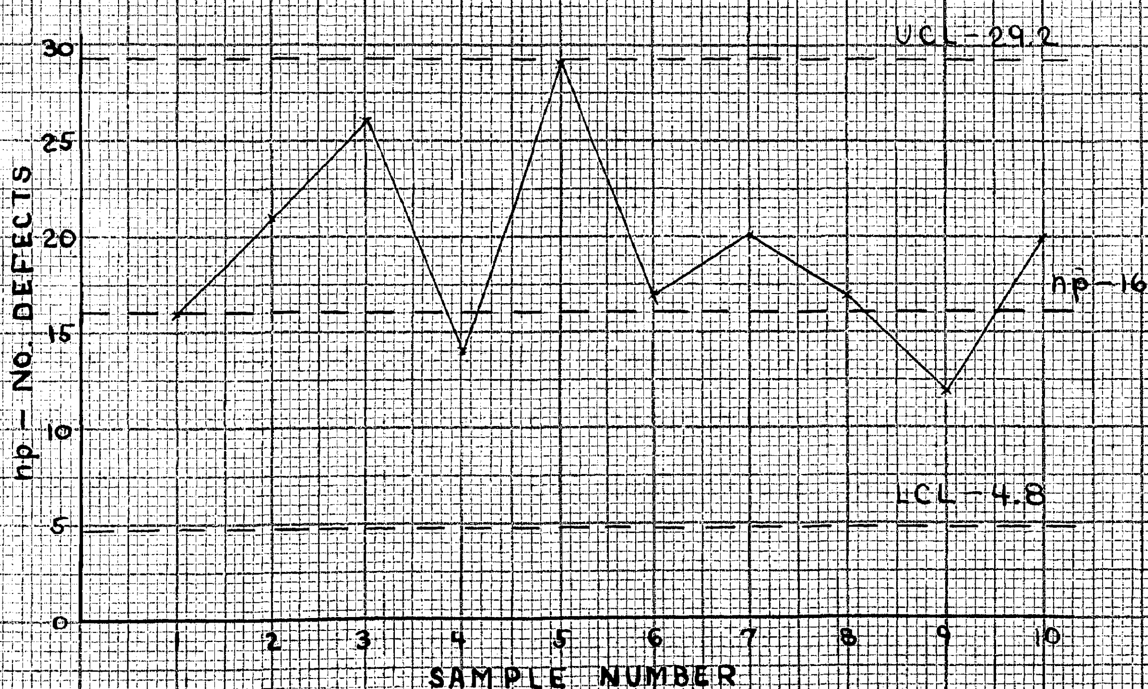


Figure 16 - np - Control Chart

Analysis of the "np" chart, Figure 16, shows one point out of control. Immediate investigation pointed toward an unnatural element that had affected the process at that time. As shown by the chart, corrective action brought the process within control.

The "np" chart is simply a "p" chart (based on constant subgroup size) with every number in the vertical scale multiplied by "n". This implies that every value of "p" is multiplied by "n" to give "np", and that the center line, "$\bar{p}$" is multiplied by "n" to give the center line "$n\bar{p}$" on the number defective chart

Every time the sample size changes, the center line of the "np" chart will shift. A change in the center line is desired to reflect a change in process level, not a change in subgroup size. Therefore, to make a "np" chart effective, a constant subgroup size must be maintained. This leaves the "p" chart as the only alternative in the situations where there is a possibility of "n" changing from sample to sample.

One of the most comprehensive treatments currently available on the entire subject of attribute charts will be found in E. L. Grant's, Statistical Quality Control.[17]

17. E. L. Grant - Statistical Quality Control - McGraw-Hill Book Company, New York - 1946 Chapters IX-X-XI.

Single Sampling Plan

If it is absolutely necessary to have all good pieces on which to work sampling inspection cannot be used. But if one can afford to accept five percent bad pieces or two percent or one percent bad, than sampling can be used effectively. However, if inspection of a characteristic must be destructive, then beyond a doubt sampling inspection must be used whether one likes it or not.

Some of the undesirable aspects of one hundred percent inspection[18] are:

1. It is costly.
2. It actually involves sorting.
3. It may result in accepting defective material, as one hundred percent inspection cannot guarantee one hundred percent perfection.
4. It may result in rejecting satisfactory material.
5. It may be impractical.

In contrast to one hundred percent inspection, reliable sampling procedures may be relatively inexpensive and in many cases no less accurate. Sampling results in considerable reduction in inspection monotony. The question of whether or not a lot will be accepted, based upon samples drawn from it, may become a game for the inspection operators. Sampling may have an effectiveness comparable to that of one hundred percent inspection, under many circumstances.

18. Statistical Quality Control - E. L. Grant, McGraw-Hill Book Company - 1946

A sampling plan can be designed to do just about whatever is desired. If the product or process could have five percent of the parts defective, but five percent would be too high, this could be arranged. It is easy to find a plan which will insure that, lots containing one percent of the pieces defective will almost always be accepted, but lots containing five percent of its pieces defective will stand little chance of being accepted. The most economical plan in a practical situation is usually a compromise between risk and amount of sampling. What is needed is a small risk and also a small amount of sampling. Before deciding on a plan the product must be examined closely to determine the allowable risk and the amount of inspection required.

One of the most common misconceptions in acceptance sampling is that a sound sampling plan is one maintained by sampling a fixed percentage of the product. There is no one best plan for all possible cases. A plan can be picked to fit the needs of any product. Fortunately, however, calculations are no longer necessary, as plans may be chosen from the many which have already been devised. One of the best sources for Sampling Plans is the Dodge-Romig[19] Tables.

The first step in applying any sampling inspection

19. H. F. Dodge and H. G. Romig, Sampling Inspection Tables, Wiley and Sons, New York - 1944

method is the selection of a random sample from the lot. This rather simple operation deserves careful consideration as every part should have equal chance of being chosen.

The next step in deciding upon a satisfactory sampling plan will be to decide upon a quality level that is acceptable. This Acceptable Quality Level (AQL) is the fraction defective that can be tolerated without serious effect upon further processing operations or customer reactions. The only real protection against unsatisfactory material is to use a sampling plan that will reject most of the lots that would seriously interfere with further processing operations. The average outgoing quality limit (AOQL) is the worst possible quality that will be accepted in the long run if all defectives found in samples are replaced with good items and all rejected lots are inspected one hundred percent and then accepted after all defectives have been replaced with good items.

The risks brought about by sampling are:

1. Passing an unsatisfactory lot as satisfactory (Consumer's risk)
2. Rejecting a satisfactory lot as unsatisfactory (Producer's risk)

Consumer's risk is the probability that lots will be accepted which are of a percent defective equal to the maximum acceptable percent defective. The consumer's risk[20] is usually ten percent. The producer's risk is the probability that lots will be rejected which are of a percent defective equal to the minimum acceptable percent defective. Producer's risk[20] is usually five percent.

Sampling plans are reduced to rule of thumb applications in determining the quality assurance that is necessary. What should the plan be based on 0.25% defective, 1% defective, or 2% defective? There is no academic approach to the problem. The only way this problem can be answered is through experience and research.

The Dodge-Romig Tables provide either lot tolerance protection at a fixed consumer's risk of 0.10 or an average outgoing quality limit protection. Producer's risk is not specified, but is kept satisfactorily low.

Single Sampling Plan - Example

Inspection receives 2560 shafts from operator "X".

AOQL = 2.5%
Process Average = 1.2%
Lot Size = 2560

Referring to the Dodge-Romig[21] tables for Single Sampling, Table SA-2.5 for Average Outgoing Quality Limit equals 2.5%, Process Average Column 1.01 - 1.50%, it will

20. E, M. Schrock - Quality Control and Statistical Methods, 1950 - Reinhold Publishing Corporation, New York

21. H. F. Dodge and H. G. Romig - Sample Inspection Tables 1946 - John Wiley and Sons, Inc., New York

be found that for a lot of 2001 - 3000 parts, the following information is shown

Lot Size	Sample Size	Allowable No. Defects
2001-3000	75	3

A sample of 75 parts should be selected at random and completely inspected. If 4 or more rejects are found in the sample of 75 parts, the lot should be rejected or detail inspected. If 3 or less rejects are found in the sample of 75 parts, the lot should be passed.

Double Sampling Plan

The operation of the Double Sampling Plan is very much similar to the Single Sampling Plan except it involves the possibility of putting off the decision on the lot until the second sample has been taken. By using the Double Sampling Plan the lot may be accepted at once if the first sample is good enough or rejected at once if the sample is bad enough. When the first sample is neither good enough nor bad enough, the final decision is based on the combined evidence of the first and second samples. If lots are very poor or very good the decisions are usually made on the first sample, hence, involving less total inspection over the Single Sampling Plan. However, if the quality of the lot is doubtful, the Double Sampling Plan has the psychological advantage on the idea of giving a second chance and consequently will average more inspection per lot than the Single Sampling Plan.

Double Sampling Plan - Example

Using the same case as explained under Single Sampling, Inspection receives 2560 shafts from operator "X" - Using the same conditions

AOQL = 2.5%
Process Average=1.2%
Lot Size = 2560

Referring to the Dodge-Romig[22] tables for Double Sampling, Table DA-2.5 for Average Outgoing Quality Limit equals 2.5%, Process Average Column 1.01 - 1.50%, it will be found that for a lot of 2001 - 3000 parts the following information is shown

	Trial 1	
Lot Size	Sample Size	No.Defects Allowed
2001 - 3000	65	1

Trial 2		
Sample Size	Total Sample	No. of Rejects Allowed
115	180	7

A first sample of 65 parts should be selected at random and completely inspected. Then,

1. If 1 or less defects are found in the sample of 65 parts, the lot should be passed.

2. If 8 or more rejects (that is more than the total number of rejects allowed after the second trial) are found in the sample of 65 parts, the lot should be rejected or set aside for detailed inspection.

22. H. F. Dodge and H. G. Romig - Sample Inspection Tables John Wiley and Sons, Inc., New York, N. Y. - 1946

3. If more than 1, but less than 8 rejects are found in the 65 parts, a second sample of 115 additional parts should be selected at random and inspected.

4. Now, a total of 7 rejects are allowed in the combined sample of 180 parts. If less than 8 rejects are found in the combined sample of 180 parts the lot should be passed.

5. When a total of 8 rejects are found, sampling may be discontinued and the lot rejected or set aside for detailed inspection.

It is generally desirable to employ the simplest possible method, even at the expense of theoretical economics. Confusion in the use of methods, difficulty in keeping records, and employee training are arguments in favor of single sampling.

$\bar{X}$ and R Charts for Variables

The $\bar{x}$ and R control charts for variables are used to provide a basis for current decisions during production as to when to look for causes of variation and take corrective action, and when to leave the process alone. The $\bar{x}$ or average chart is essentially a simplified method for determing the limits of variation that can be expected in the averages of small samples taken from a constant-cause system, using the range as a measure of dispersion. Sample averages falling outside the estimated control limits point out situations where assignable causes are so large that investigation will undoubtedly call for corrective actions.

In order to get control of a process, it is not only necessary to know the behavior of a process between samples, but also to determine whether or not assignable causes exist within the samples. Thus, the two charts show the presence of any irregularities between samples by the $\bar{x}$ chart and within the sample by the R chart.

Sample size[23] most common in industry is five, however, Shewhart suggests four as the ideal sample or subgroup size. It is desirable that sample size be as small as possible so as to give a minimum opportunity for variation within the sample.

Table 2 shows the $\bar{x}$ and R values of the basic data shown in Table 1. The sample or subgroup average $\bar{x}$ was obtained by adding together each measurement in the subgroup or sample and the sum is divided by the number in that subgroup or sample. The Range, R, is the difference between the highest and the lowest values in the subgroup or sample.

Values of $\bar{x}$ and R are usually plotted on the verticle scales and the sample number usually on the horizontal scale. See $\bar{x}$ and R control chart, Figure 17.

The central line, $\bar{\bar{x}}$ on the $\bar{x}$ chart, is the average of all the $\bar{x}$ values. The center line, $\bar{R}$ on the R chart, is the

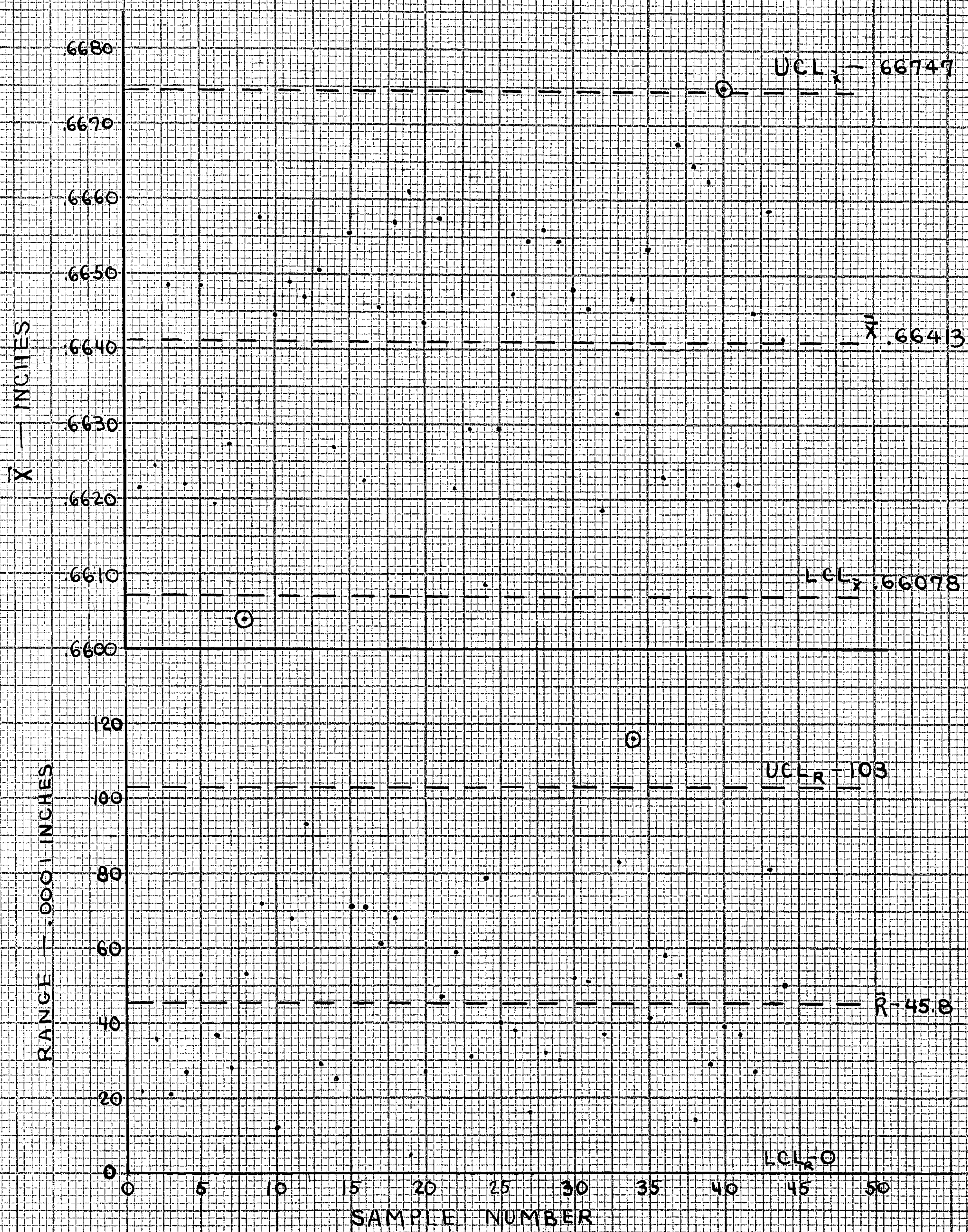
2 3. E. L. Grant, Statistical Quality Control, - 1946 - McGraw-Hill Book Company, Inc.

Sample No.	$\bar{x}$	R x (.0001)	Sample No.	$\bar{x}$	R x(.0001)
1	.66212	22	23	.66295	31
2	.66242	36	24	.66085	79
3	.66485	21	25	.66298	40
4	.66220	27	26	.66478	38
5	.66485	53	27	.66548	16
6	.66192	37	28	.66560	32
7	.66273	28	29	.66542	30
8	.66040	53	30	.66480	52
9	.66575	72	31	.66455	51
10	.66445	12	32	.66188	37
11	.66490	68	33	.66318	83
12	.66470	93	34	.66470	116
13	.66505	29	35	.66535	41
14	.66270	25	36	.66230	58
15	.66555	71	37	.66675	53
16	.66222	71	38	.66648	14
17	.66458	61	39	.66622	29
18	.66570	68	40	.66750	39
19	.66610	5	41	.66022	37
20	.66435	27	42	.66450	27
21	.66578	47	43	.66585	81
22	.66212	59	44	.66412	50
			Totals-	29.22178	2019 x(.0001)
			$\bar{\bar{x}}$ =	.66413	
			$\bar{R}$ =		.00458

Table 2

Data Sheet for $\bar{x}$ and R Values for Table 1 Data.

Figure 17 - $\bar{x}$ and R Control Charts



average of all the R values of the data. The control limits are calculated as follows:

$$U\,C\,L_R = D_4\bar{R}$$

$$L\,C\,L_R = D_3\bar{R}$$

$$U\,C\,L_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R}$$

$$L\,C\,L_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R}$$

D_3, D_4, and A_2 are standard factors[24] used for determining the three sigma control limits for $\bar{x}$ and R charts. For sample size of four:

$$D_3 = 0 \qquad D_4 = 2.28 \qquad A_2 = 0.73$$

Since $\bar{\bar{x}} = .66413$ and

$\bar{R} = .00458$

The control limits for R chart would be

$$U\,C\,L_R = D_4\,\bar{R} = 2.28\,(.00458) \qquad\qquad L\,C\,L_R = D_3\,\bar{R} = 0\,(.00458)$$

$$U\,C\,L_R = .0103 \qquad\qquad L\,C\,L_R = 0$$

The control limits for $\bar{x}$ chart would be

$$U\,C\,L_{\bar{x}} = \bar{\bar{x}} + A_2\,\bar{R} = .66413 + 0.73(.00458) \qquad\qquad L\,C\,L_{\bar{x}} = \bar{\bar{x}} - A_2\,R = .66413 - 0.73\,(.00458)$$

$$U\,C\,L_{\bar{x}} = .6675 \qquad\qquad L\,C\,L_{\bar{x}} = .6608$$

The control limit lines are drawn on the respective charts at the proper values. Lack of control is indicated

24. E. L. Grant - Statistical Quality Control - 1946, McGraw-Hill Book Co., Inc., New York Table C, Appendix III.

by points falling outside the control limits of either the $\bar{x}$ or R charts. A constant-cause system will seldom be responsible for points falling outside control limits. When all points fall within the control limits, a constant-cause system exists as no assignable causes of variation are present.

Summary

In any manufacturing process, variation is inevitable. Quality will vary no matter what the product is or how critical a control has to be maintained. The frequency distribution charts describe the pattern of these variations. Knowledge of these patterns of variation are helpful in determining whether the variations are stable or unstable. Frequency distribution charts supply a basis for action by their unusual distribution matter.

The techniques of sampling inspection are based on the theory of probability. Whenever sampling inspection is in order, the basic purpose of inspection is to collect data. The principle of acceptance sampling is based on the fact that, for a product derived from a common origin, the inspected parts reflect the nature of the process and also reflects the nature of the uninspected pieces produced by the same process. Much acceptance inspection is on a sampling basis. It is apparent that all tests on destructive items must be done on a sampling plan. In a number of cases a good sampling inspection plan may actually give better quality assurance than 100% inspection. Single and Double Sampling plans as developed by H. F. Dodge and H. G. Romig may be selected to give any desired quality assurance.

Control charts are powerful analytical tools, but like all keen instruments they give best results when used with skill and understanding. There are two kinds of control charts; charts for variables, in which quality is described quantitatively in terms of dimensions, weights or other characteristics; and charts for attributes, p and np charts, in which inspection is by GO-NO-GO gauges or visual where the product is either classified good or bad. There is no substitute for experience and common sense in making the most out of control chart analysis. Proper control has been achieved when the sample of product is centered between the specification limits. The areas between the control limits and product limits on the charts create a desirable situation in that as the process gets out of control, there is time to take corrective action before defects are actually produced.

CHAPTER IV

PLANNING FOR QUALITY CONTROL

Scope of Program

When a company installs a program of quality control, it is normally expected that the entire business operation will benefit. The quality control department should not work by itself but it should help, and should be helped by, sales, production, engineering, and top management. Successful operation of the quality control department depends on close co-operation with these other groups.

Quality Control can get off to a poor start because of insufficient or lack of ground work. It is for this reason that a good selling job within the company is essential for the future success of quality control. When departments concerned with quality control have been orientated in its functions and applications, it is rather obvious that these departments will be in a much better position to assist in quality control.

It must be clearly understood that quality control is not a cure-all for management, but rather a program jointly administered and guided by the various departments of an organization. A well-planned program should cover all operations from the initial product design to the final inspection function.

Objective of Quality Control Program

The overall objective of any quality control program is usually the reduction of scrap. A reduction in scrap reflects a cut in production costs and possibly a cut in price by sharply reducing the proportion of finished products that fail to come up to specification. A decrease in the amount of rejects besides economizing on labor and materials also improves producer-customer relations by offering improved quality of the final product.

Competition spurred the use of quality control as one possible way of getting a step ahead of the pack. Unbelievable potential savings can be made through the reduction of rejected goods, re-working and inspection costs, and out-and-out waste. Quality control programs achieve this enviable objective by applying the laws of probabilities to spot trouble in a production line before defective goods start piling up.

Management Review of Program

Top management must consider and review the quality control program to create a definite understanding of what lies ahead. Many executives often make the statement, "Our company installed a system of statistical quality control". This type of statement may be misleading as statistical quality control is not really a system, it is merely a set of tools or methods that may be applied to certain problems of specification, production, and inspection. Management must realize that for best results each application of quality control should be tailor-made for its own particular circumstances.

Furthermore, the organization of any program that requires co-operation among departments constitute a problem for top management. In many companies department heads and foremen are judged in terms of conformance to their budgets, hence their decisions and actions tend to rely on the effect on their budgets and not necessarily on the end result for the company. It sometimes happens that a small increase in expenditures in one department will bring about a much larger saving in another or even in the same department. Concentration on the individual budget in many cases constitutes a serious obstacle to the effective use of quality control. Almost every application of quality control or policies related to product quality crosses the lines of departmental responsibility. It is for this reason that top management should make all decisions related to quality and also formulate its stand on definite basic policies for control.

Division of Authority

Although actual inspection is closely allied to productive operations, the function of quality standards and controls should be separate from the actual manufacturing function. Examination of the organizational charts of numerous companies shows that many companies have adapted the policy of placing the quality department on the same level as other manufacturing and service departments, each in turn reporting to the top manufacturing executive. This results in an unbiased operation of the part of quality control, which is essential in establishing and maintaining proper quality performance. Maintenance of a high level of quality requires a quality department which cannot be readily overruled by the shop.

Most of the large highly productive mechanical industries have built up an organization to operate under the quality control viewpoint. Individual differences of structure, however, exists among all companies. Organization[25] for quality control is considered from the viewpoint of:

1. To whom is quality control responsible
2. External structure
3. Internal structure

Organization problems must not only be considered from the viewpoint of good practice, but also from that of human nature and personalities. The problem of Organization is covered in detail in Chapter V, Quality Control Organization.

25. Inspection Organization and Methods - Thompson - McGraw-Hill Book Company, Inc., New York 1950

Selection and Training of Personnel

The application of any new system necessitates the need for selecting and training personnel to carry out the predetermined program. Selecting personnel for quality results is a rather important job as knowledge of statistical methods alone is not sufficient. The normal place to look for the required personnel is within the plants organization. These people are generally preferable because they are familiar with the products and the field to be covered by the quality program. The basic requisits[26] of a good Quality Engineer are:

a. Engineering judgement
b. Imagination
c. Diplomacy and tact
d. An understanding of production problems
e. Basic knowledge of mathematics

Training of personnel may be approached by many methods. The choice of any method will vary with the product policy and facilities of the company. The two basic training practices for quality engineers are:

a. University training
b. Training by consultants

Most colleges and universities have undertaken programs aimed at Statistical Quality Control. The growing

26. C. R. Scott, Jr., S K F Industries - Round Table Discussion on Quality Control

interest of industries along the lines of quality control has necessitated these programs. The subject of quality control is usually included in the general curriculum of most schools, however, it is still being treated as a special technical subject available for local industrial personnel. Acceptance in these special classes on quality control usually does not require an engineering background, but does require activity along the lines of inspection or quality control.

Quality control courses usually give the student a well-rounded background in the techniques of quality control. For those companies that are not equipped to conduct their own training program, the college and university courses provide the best opportunity to educate industrial personnel.

When large companies attempt to undertake a plant-wide quality program, it may become necessary to acquire outside help from consultants. In such cases the consultants will set up a training program as one of their functions in educating shop personnel along the line of quality control. Such a program can either be held inside the plant or outside the plant according to the facilities available. By all means, a reliable consultant should be engaged or valuable time and money will be lost.

It must be remembered that no training program is effective if the personnel does not have the physical and mental equipment as well as adequate potentialities.

Analysis of "Gold in the Mine"

The phrase "Gold in the Mine"[27] is used frequently to represent the monetary loss in manufacturing which could be reclaimed in part by better planning and control. What is your "Gold in the Mine"? This question can be answered rather easily by determining what present costs would disappear if all the defects disappeared. In other words add up the losses through scrap, the use of too much material, rework, extra inspections, extra operations, discount on seconds, customer complaints, etc. The accounting department can be a valuable aid in obtaining the above information. Needless to say there is a lot of gold in the mine.

Before entering any quality program a predetermined goal must be set up. How much can be saved with what expended effort? Knowing what gold is in the mine, it can be determined whether or not it is worthwhile to go ahead with the program.

Tangible Losses - Intangible Losses

The losses represented by the gold in the mine may be broken down into two classes - tangible losses and

27. J. M. Juran - Management Round Table Discussion at New York University - 1948.

intangible losses. A list of recognized tangible losses would include the following:

Scrap
Junk
Rework
Extra operations
Cost of sorting
Added assembly work
Consumer quality adjustments
Costs of complaint handling
Discount on seconds
Waste of materials
Delays in production (Slows up final line)
Cost of making good on quality guarantees

The above list are by no means the only tangible losses that may occur. Each company and industry has its own peculiarities which either add or subtract to that list.

If a careful analysis of the causes of the tangible losses is made, the profitable seams in the gold mine can be identified. It is generally agreed by quality control engineers[28] that after such an analysis relatively few causes are responsible for one-half to two-thirds of all the losses, or gold in the mine.

Intangible losses, although they cannot be readily measured, are just as important as the tangible losses. The two most common intangible losses are: (1) good will of customers and (2) friction between departments. Intangible losses may best be reduced or eliminated by attacking their source, the tangible losses. As stated above

28. J. M. Juran - Management Round Table Discussion at New York University - 1948.

this can best be accomplished by a quality control program.

Review of Customer Complaints

Quality of performance as well as design can and is being improved through the use of customer complaints. No one can better tell how well a product stands up in actual use, or how a product may be altered in design to meet actual demands, than the users themselves.

A service or repair department's periodic report, which should list and group the various reasons for the customer's complaint or return of product, usually pinpoints a few particular items which seem to cause the most trouble. An extensive survey on these items will undoubtedly improve the product and at the same time cut down the number of customer complaints. Extremely high frequency of failure on any one item may also demand an engineering investigation to determine any design changes that might improve the quality of a product.

Building Quality Assurance

Prevailing practices and habits of the shop personnel, for the most part, are still those of low quality and high cost. Therefore, before a quality product can be consistently made, it is quite necessary to build quality assurance. There are a few methods that could be tried to get back to high quality and low cost.

At one extreme is an appeal to the personnel, pointing out that competition demands that costs must come down and that quality must go up. This type of appeal, however, is bound to fail because it is not founded on a planned program for action.

At the other extreme is the effort of getting after the really bad instances as they crop up. This effort is likewise doomed to fail because it is just picking away at the problem instead of going after the basic causes by an organized plan of action.

The method most apt to be successful is the preparation of an internal advertising campaign proving to each employee that they have a personal stake in the company's quality reputation. This internal advertising campaign can be accomplished by posters, slogan contests, reports from customers, moving pictures, articles in house organs, etc. The basic theme being the installation of an attitude of quality-mindedness or Pride in Performance in each employee. Once an operator is in a state of quality-mindedness and shows pride in performance, quality can be obtained and assured.

Summary

There is a wide gap between the theory and the practical application of statistical quality control methods.

Some common mistakes in their use are: uneconomic applications, poorly organized or planned program and lack of employee understanding and training. A quality control program, to become successful must be well planned. Management in all cases should be called upon to review and subscribe to the scope and objective of the program.

An analysis of the "Gold in the Mine" provides an adequate starting point for determining the scope of the quality program. This analysis evaluates those parts or jobs that are perpetual offenders of quality. Concentration on these perpetual offenders would result in immediate visible success of the program. Future success depends on building a state of quality-mindedness in each and every operator.

In selecting and training personnel for the quality control program, it must be remembered that no program can be expected to be effective if the personnel doesn't have the physical and mental equipment as well as adequate potentialities.

CHAPTER V

QUALITY CONTROL ORGANIZATION

Nature and Purpose of Organization[29]

Proper organization is one of the primary steps in management development of any enterprise. Operation and operating methods depend largely on the organization which has been built up. A well organized business has gained an excellent start toward effective operation. The organization which is well constructed is typified by smooth flow of detail throughout the executive organization. A poorly constructed organization is typified by executives who are continually struggling with a mass of detail.

The purpose of building up an organization is to provide for a daily routine and effective operation of a business or department with a minimum of direction. Organization carries out its purpose by determining the scope and limits of each individual or department together with their relationships and contacts with each other. Application of the fundamentals of organization will differ in two different businesses. The size of a business also has an effect on the way in which the organization is developed. In a small business it is possible to develop essentially the same type of organization as developed in a large business, except that the duties of several

29. Inspection Organization and Methods - Thompson - McGraw-Hill Book Co., Inc., New York - 1950.

people in the large business will necessarily have to be combined in the small one.

Organization Charts - Place of Quality Control in Organization

The application of the same fundamentals of organization can be made in many different ways. These differences in application are responsible for the development of distinct types of industrial organizations. The four recognized types of industrial organizations[30] are:

1. Line or military organization
2. Functional organization
3. Line and staff organization
4. Committee organization

The organization chart is prepared by setting down on paper the structure of the organization by indicating positions or departments and then showing the lines of communication between them. Lansburgh and Spriegel in their book, "Industrial Management"[31] provide a well-rounded discussion on all types of organizations and organization charts. In studying any organization chart it must be remembered that the titles given individuals or departments will vary from organization to organization according to the notions of the organizer, however, the duties performed will be essentially the same.

The first consideration in the organization of a quality department is to whom will the department be

30. Cost and Production Handbook - Alford, Page 149
    The Ronald Press, 1942

31. Industrial Management - Langsburgh and Spriegel
    Chapter VII, John Wiley & Sons, New York - 3rd. Edition.

responsible? The effectiveness of the control is dependent to a great extent on this important point. Organizational structures that have proved successful are shown in Figure 18 and Figure 19. A less desirable organizational structure is shown in Figure 20. There has been no attempt to show all the departments or sections of any company. It is intended primarily to show the relation of the quality control department to the rest of the company.

In some of the most successful applications, the quality control department reported directly to the plant manager as shown in Figure 18, thereby it was not subordinate to the functions of engineering or production. Actual success of this scheme of organization is dependent largely on the quality group in securing volumtary co-operation from engineering and production without using its full authority.

In some instances, the quality control group reports to the Chief Engineer, as shown in Figure 19. This arrangement is quite satisfactory when the total quality control and engineering personnel are few in number, but it places considerable burden upon the chief inspector in the case of a large plant. When the quality control program is intensive, involving considerable personnel, the quality control activity may be nearly as large as the

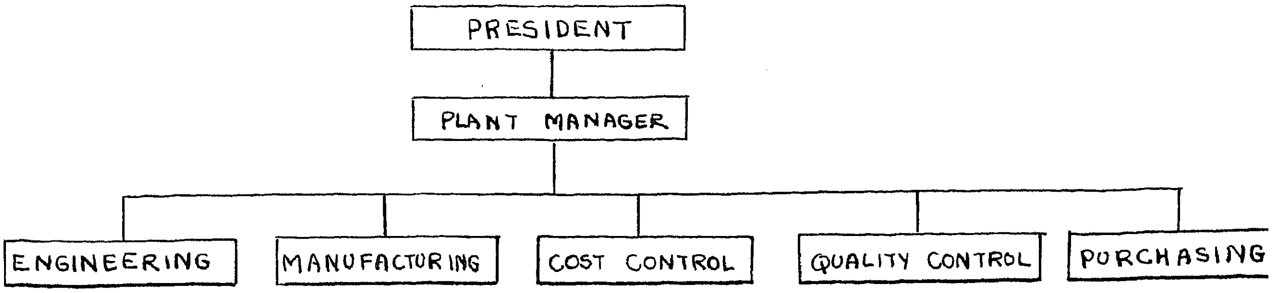


Figure 18

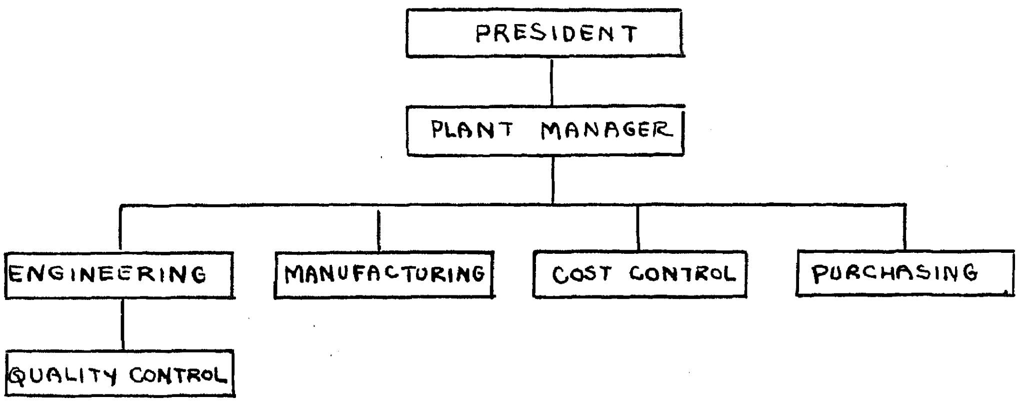


Figure 19

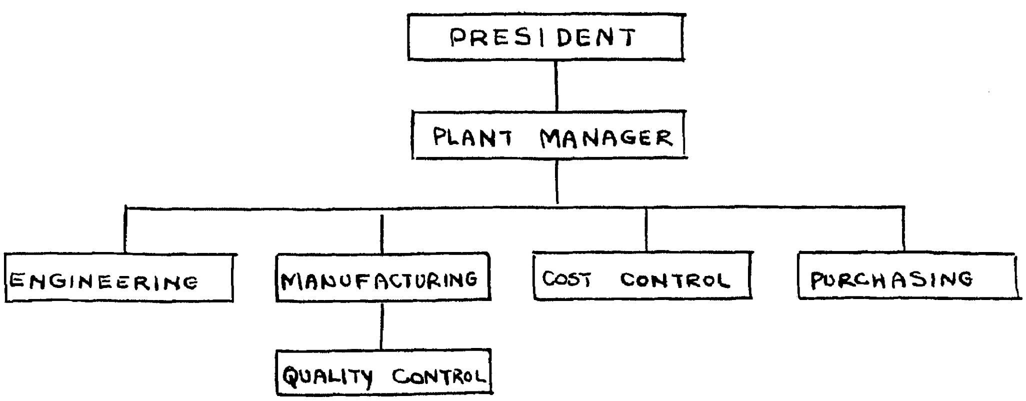


Figure 20

Organizational Position of Quality Control Department.[32]

32. Quoted by permission from Quality Control in Industry - J.G.Rutherford - Pitman Publishing Corporation , New York 1948.

engineering department. Good organization, then, demands that quality control be a separate department, responsible to top management.

The quality function is very rarely made responsible to manufacturing as shown in Figure 20, for it is almost universally accepted that quality control can be effective only if it is not under pressure from those two phases of business operation. It must be clearly understood, however, that with the proper managerial support and the necessary ability and personality in the quality engineer, the quality control department can be successful no matter where the position in the organization chart.

Organization of Quality Control Department.

The structure of the Quality Control Department may be considered from two viewpoints: (1) that of external structure and (2) that of the internal structure as stated on page 62. Large corporations, with only one plant, or one with the divisions located closely together, usually operate inspection under centralized control, as in Figure 21. Centralized authority in this manner has several advantages; it furnishes a single point at which problems involving inspection may be settled, gives more definite assurance that a set quality level will be held, and decreases the chances of dispute between divisions.

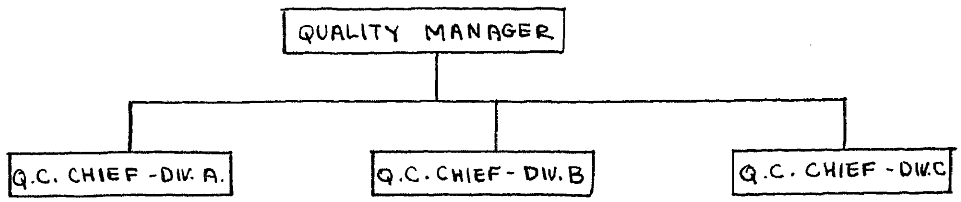


Figure 21 - Centralized Supervision of Quality Control Department.

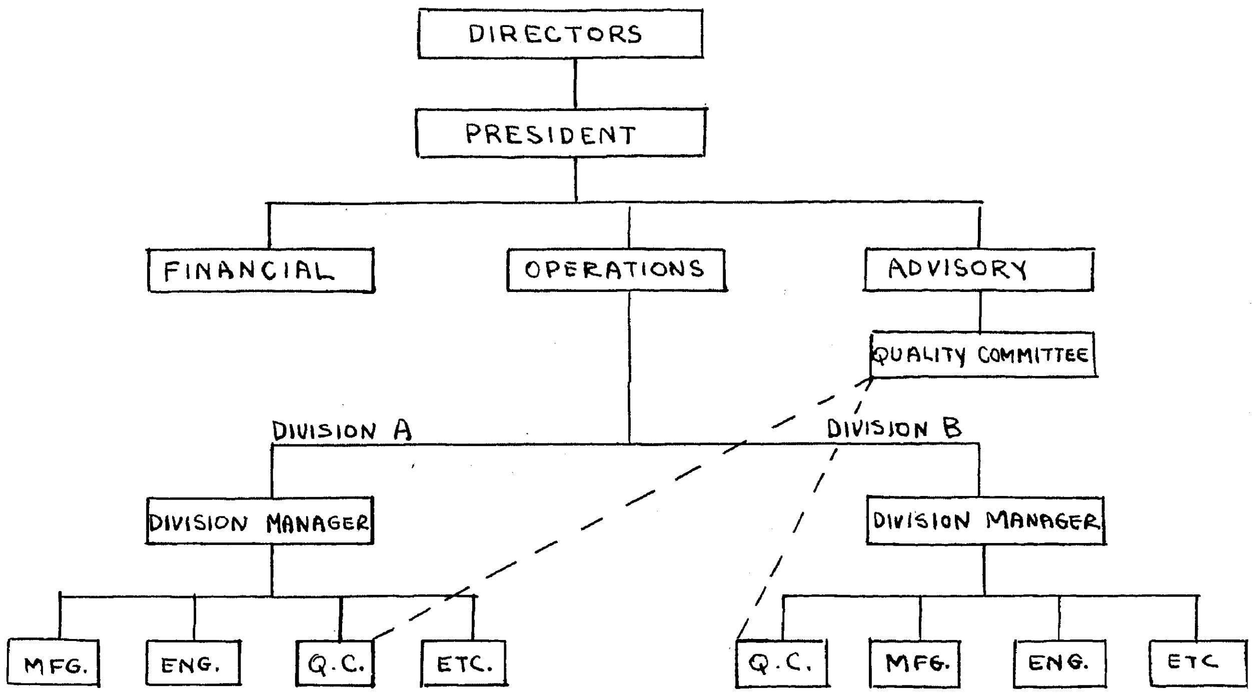


Figure 22 - Organization Chart of Corporation.[33]

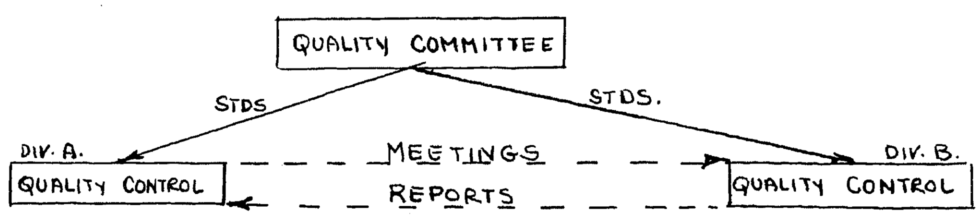


Figure 23 - Simplified Organization of Chart (Figure 22)[33]

33. Quoted by permission from Quality Control in Industry- J. G. Rutherford. Pitman Publishing Corporation, New York, New York - 1948.

When the divisions of a corporation are widely spread, the usual practice is to have the quality control chief report to someone in that division as shown in Figure 22.

A centralized committee at the main office issues data on tolerances and functional checks and exercises a light control over all plants to assure a common standard of quality. Periodic meeting between the chief quality control men of the various plants and the exchange of reports is another means of co-ordination. The quality control departments of each division is usually an independent unit with the co-ordinating agency being the central quality committee. A simplified organization chart of Quality Control Department of the Corporation (Figure 22) would appear as shown in Figure 23.

The internal structure of a quality control department varys with the size of the plant or corporation. In small plants the quality control function could be personally exercised by the quality control man. In larger plants, the size or complexity of the enterprise may make it impossible for the quality control man to personally discharge these responsibilities. Such cases usually require a staff quality control man with as many assistants as needed. The overall pattern of the internal structure of the quality control department may be covered by the three classic types: straight-line, line and staff, and functional.

The straight-line type, (Figure 24) for many purposes is the most effective form of organization. This form is the basic framework for the greater part of most quality control departments. There is little opportunity for misunderstandings or overlapping functions as the relative positions and authority of each supervisor and person is clearly defined. The greatest disadvantage of the straight-line organizational structure is that it places a heavy responsibility on the top men. To overcome the disadvantage of the straight-line organization, the line and staff type (Figure 25) was developed. Staff members do not have charge of the men doing the work, but direct how the various phases of the work are to be done through the line supervision. This arrangement has proved successful and is used throughout industry.

In the functional organization (Figure 26), the foreman has a number of superiors, each directing a particular phase of the work. Under the foreman the organization reverts to a straight-line type. The possibility of overlapping fields of endeavor of the functional directors and the confusion confronting the supervised people contribute to the inherent weakness of this setup. Although there are a few applications of this type of organizational structure to quality control, it is not a highly recommended structure.

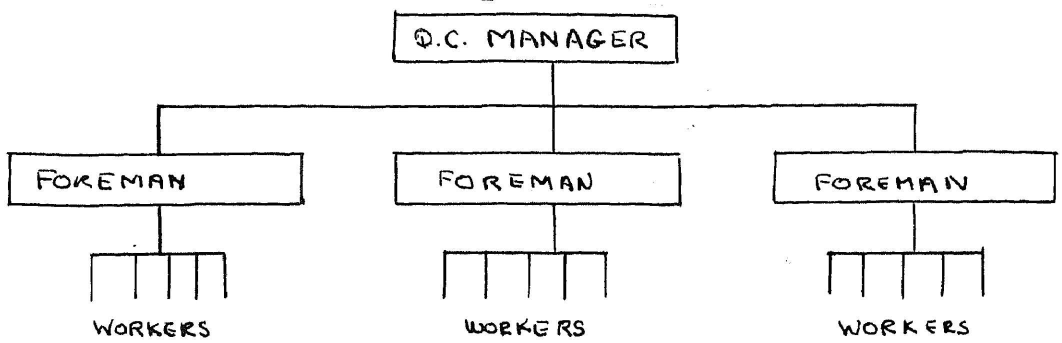


Figure 24 - Straight Line Organization.

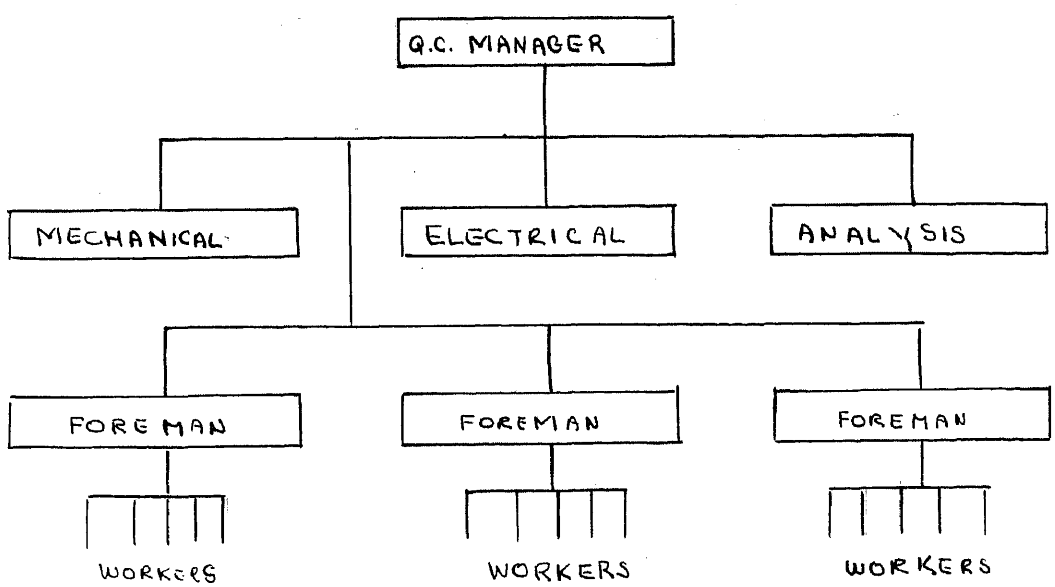


Figure 25 - Line and Staff Organization.

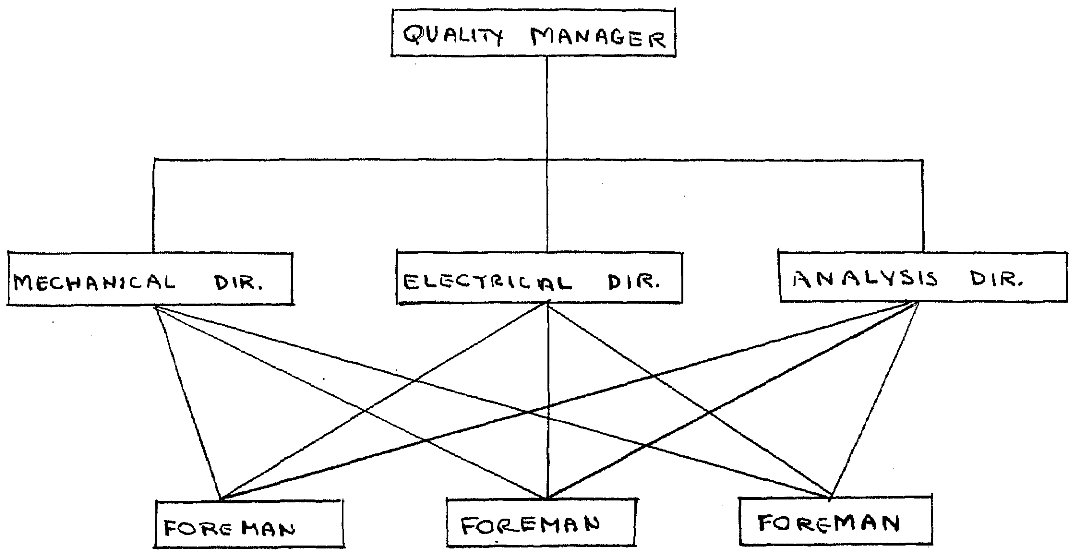


Figure 26 - Functional Organization.

Relation of Quality Control to Inspection

What should be the relation of the quality control staff to inspection? This question usually arises when the outline of responsibilities of the quality control staff is reduced to practice. It is often suggested that the quality control staff cannot adequately discharge its responsibilities without being allied with the inspection organization. The inspection department is called upon more often than any other group to make decisions affecting quality of the products. Where the quality control manager is responsible for both inspection and the quality control staff, he may be better informed and rather acceptable toward the revision and modernization of the plant inspection practices than an independent chief inspector. The quality control manager would normally be in a good position to integrate the inspection methods with the overall plant quality control program.

Functions of Quality Control Department

No matter how complex or how simple the quality program may be the functions and responsibilities are the same for almost all quality organizations. A. V. Feigenbaum in his book, "Quality Control - Principles, Practice and Administration"[34] lists the most important functions and responsibilities as follows:

34. A. V. Feigenbaum - Quality Control - Principles, Practice, and Administration - Chapter IV, Pages 46 & 47, McGraw-Hill Book Company, Inc., New York - 1951

1. To aid management in the preparation, adoption, and continued evaluation of a factory-wide program of quality control, expressed in terms of written company policy.

2. To advise line, staff, and functional groups in Manufacturing and Engineering as far as their quality control activities are concerned.

3. To develop and to maintain for top management an effective product quality appraisal system.

4. To stimulate quality research.

5. To maintain or stimulate quality control education.

6. To aid management in stimulating a quality-minded attitude throughout the plant.

7. To assist, and in some cases to act for, management in the actual details of administrating and co-ordinating the factory-wide quality control program.

8. To establish and to perform certain quality control services.

9. To advise management in the product-quality aspects of the establishment of new plants and manufacturing areas.

10. To aid Marketing and Sales in their merchandising and product-planning activities and in product advertising campaigns.

11. To develop a competent and efficient group of men and women to carry on the quality control staff functions.

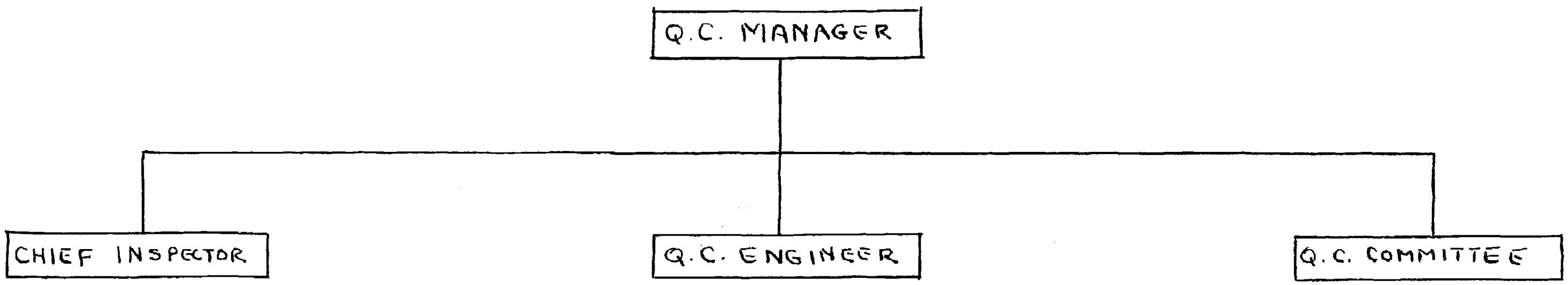
Although the above functions and responsibilities are quite general, it is rather obvious that the best plan in any particular case will depend on many factors based on the needs of the individual plants. The abilities and personalities of the members of the quality control department also tend to dictate the exact responsibilities of a quality control department.

A typical quality control organization chart outlining the duties and responsibilities of the key personnel is shown in Figure 27.

Summary

Effective quality control is dependent on the effectiveness of plant organization as well as quality organization. A good organizational set-up for quality control usually requires a separate department for quality control that is responsible only to top management. Internal structure of the quality department may follow one of the following forms: straight-line, line and staff, and functional.

The functions and responsibilities of the quality control department are the same for every plant except for the differences in magnitude. The best plan usually depends on the needs of the individual plants. Abilities and personalities of personnel in the quality control department goes a long way in formulating the responsibilities of the quality control department. Effective organizational co-ordination depends on adequate follow-through of the duties and responsibilities set-up for the plant's key personnel.



Quality Acceptance
Receiving
Process
Finished Goods
Test Equipment
Gage Maintenance
Day-to-Day Trouble Shooting
Salvage

Prevention Function
Process Capability
Design of Sampling Plans
Analysis of Data
Statistical Methods
Training in Quality Control
Design of Experiments

Assurance Function
Quality Audit
Check Inspection
Customer Complaints

Figure 27 - Duties and Responsibilities of Key Quality Control Personnel.

CHAPTER VI

INSTALLATION OF A QUALITY CONTROL PROGRAM

Formulation of Program

A program of Modern Quality Control may be suggested from any of several places in the factory. Top management, being impressed with the success of quality control programs in other plants, may initiate the need of a Quality Control program in their own plant. In some cases a program may be proposed by the head or heads of various departments such as chief engineer, chief inspector, or plant superintendent. Modern Quality Control, on the other hand, may be proposed to eliminate the extreme pressure in the plant due to high manufacturing losses and many field complaints. No matter how the Quality Control program is proposed, the first major assignment is to formulate a practical plan for initiating and outlining the ultimate objectives of the program for the plant.

In developing a quality control program it is essential that the plant's quality needs should be analyzed very carefully. The program being introduced should be somewhat tailored to the requirements of the individual plant. By all means it should not be a plan taken from another plant. The ultimate scope of the quality program is dependent on the economic balance between the quality problems in the factory and the cost of the minimum control required to solve them.

Selling Top Management

After the Quality Control program has been formulated, it is very important that top management accept this proposed program. When Management requests certain adaptations or changes be made in the program, they should be fully considered and incorporated whenever possible. If top management is not completely sold on the proposed Quality Control program, the effectiveness and success of future selling of the program to the remainder of the organization will be greatly affected. In some cases top management may grant a tentative approval with the complete approval contingent upon the results obtained from the pilot quality control applications.

The introduction of any quality control program usually produces a certain degree of resistance among plant personnel. Resistance may be kept to a minimum by properly informing the plant personnel of the procedures and objectives of the program. Top management should present the essentials of the quality control program to the key plant personnel. By doing this, top management demonstrates that it fully supports the proposed quality control program. This presentation or introduction of the quality control program by top management to the plant personnel may be carried out by any or all of the following ways:

(a) Formal dinner with presentation of program.

(b) Use of Slide Film as media for presentation.

(c) Informal plant meeting.

Management cannot be expected to accept quality techniques immediately. In some cases quality control must be introduced slowly in order to get the full cooperation of management. It is advisable to stress the techniques of quality control during the introductory period so that management will be in a position to point them out to other members of the organization.

After top management has recognized the benefits of quality control, the actual selling of the quality control idea is carried to the machine operator, and then to the first layer of supervision just above him. The quality engineer, or group that is installing the program, does the selling with the support of top management. Several failures of quality control programs can be traced to efforts of management to impose quality control from above instead of permitting the quality engineer to gradually break in the lower echelon workers. The machine operator, when shown the benefits he will receive through control techniques, sometimes aid in convincing supervisory workers and foremen. Success of this system of introduction stems from the fact that each succeeding level within the plant is in closer touch with the one above it.

Union Viewpoint

Unions are generally interested in anything that directly or indirectly benefits the worker. Knowing and understanding the objectives and the results obtainable through quality techniques, union officials would undoubtedly favor a quality control program. Before introducing the program to the plant, the union should be approached so that their viewpoint or criticisms may be considered and included in the program if at all necessary.

Union officials can usually be sold on the point that an efficient quality control program increases the rate of "in tolerance" production. Consequently this enables the piece workers to get more pay in their envelopes because more of the work turned out is of acceptable quality.

Appeal for Pride of Performance and Quality Mindedness

The greatest source of quality in a plant is the conscientious workmanship of its people. Without the proper attitudes among all factory employees, no quality program could enjoy real success. A real feeling of quality responsibility must be developed among all members of the plant's organization. This important spirit of quality-mindedness must extend from top management right through to the men and women at the bench.

The growth of this quality-mindedness attitude may be fostered by communicating to all plant personnel the quality objectives. Some of the most popular means of communication are:

(a) Quality cartoons.
(b) Plant papers.
(c) Films.
(d) Quality contests.
(e) Quality Control publicity releases.
(f) Meetings - Supervisor-Employee.

The quality attitude, no matter what it may be, is reflected by the operators. A quality-minded plant is a plant where the organization lives and acts quality every day of the year.

The factory with poor relations between workman and supervisor is not usually a quality-minded factory. In order to insure quality-mindedness throughout the plant, there must be satisfactory working conditions, both physical and human. Therefore, adequate work space, illumination, proper gage facilities, congenial surroundings, etc., are all very important.

Success of the employee participation in the campaign for quality-mindedness can be judged by the extent to which all employees recognize the importance of their individual efforts in producing a product of acceptable quality.

Appreciation of Human Factors

Of the two factors affecting product quality, technological and human, the human is of equal importance. The human factor that deals with operators, foremen and other factory personnel is primarily a matter of human relations. Effective human relations is quite basic to good quality control. A feature of this activity is its positive affect in building up operator responsibility for, and interest in, product quality. Since a pair of hands performs the important operations which affect the product's quality, it is very important that these hands be guided in a skilled, conscientious, and quality-minded way.

Tool and Gage Control

The quality of the parts being produced cannot be any better than the tools and gages needed for the job. To assure continued accuracy of these tools and gages it is quite necessary that they be checked by some systematic method. A good tool and gage system calls for rigid control and inspection of all tools, gages, measuring, testing and other devices necessary for producing a conformance product. It is necessary to set up a system, whereby all tools and inspection equipment are checked by an established schedule based on past experiences, purpose, degree of usage, etc. Needless to say, all checks should be made with suitable measuring and inspection equipment.

The formality of checking tools and gages without furnishing any records of such checks, is no conclusive evidence that proper control is being maintained. Therefore, inspection records of all checks made on all tools and gages should be required and rigidly maintained. These inspection records will provide valuable information on the history and previous inspections of all tools and gages. The inspection records should be up to date and available for review or consultation at all times.

Incoming Material

There is no better way to start a quality program in a plant than by stopping the receiving of non-conformance parts from vendors. Receiving non-conformance parts raises havoc within a plant and many times requires additional costs by reworking the individual parts or the assembly in which it had been used. The quality obtained by using these bad parts cannot be any better than the quality of the parts used. In order to insure a high quality standard, rigid inspection discipline must be maintained on all items received.

The quality of incoming material may be controlled by various types of inspection, among which single or double sampling and control charts are most frequently used. Condensed single and double sampling tables provided to incoming inspection are based on the Dodge-Romig[35] standard tables. These tables provide for a sufficient degree of inspection on early shipments to assure that the vendor is meeting the quality standard required. They also provide for reduced inspection without excessive risk of accepting poor material after vendors have established their reliability. Any failure of the material to meet the requirements will result in reverting to the original inspection requirements.

If destructive tests are required to check for a given characteristic, only a few pieces need to be tested from each shipment. The results of the list can be plotted on control charts to indicate whether variations in quality of material received are normal, or whether they are abnormal and indicate some significant change in the vendor's process. If the control chart indicates that the material is abnormal or out of control, the vendor is instructed to make corrections before the variation becomes so great as to produce material out of tolerance

35. Sampling Inspection Tables - Dodge-Romig - John Wiley and Sons, New York - 1944.

and consequently requiring rejection.

Incoming material inspection reports, to really become effective, should be recorded and filed along with previous inspection reports. Before inspecting any incoming part, a quick glance at the compiled incoming inspection reports on that particular material would greatly assist the inspector by giving first-hand information concerning the reliability of the vendor and the previous history on the product.

When starting a Quality Control Plan, the incoming materials inspection group is considered the best place to start as it assures the acceptance and consequently payment for conformance material only. Furthermore, by starting the Quality Control Program in a department that is somewhat divorced from the shop itself, changes in the plan can be made without too much attraction.

Pilot Plan

The introduction of statistical quality control inspection methods in the shop must be done slowly, step-by-step. Inspectors, production supervisors and workers must be persuaded to co-operate fully in its proper use. But once started, a properly installed program soon makes its value apparent.

"What should be installed first, Acceptance Sampling or Process Control"? There is no set rule governing the installation of a quality control program, but usually individual company situations dictate the type of control needed first. When incoming inspection represents a problem, it would be wise to start the installation with Acceptance Sampling Plans. The control of "in process" manufacturing can be accomplished with the adoption of Process Control Charts.

The first step in introducing Statistical Quality Control is to select a specific job in a department where considerable difficulty is being experienced in maintaining proper quality. This is important, both because management will observe the results on a small scale before adopting a new procedure throughout the plant, and because inertia of employees accustomed to old procedures may be best overcome in slow stages. It also will give those directly involved an opportunity to become accustomed to the new program gradually.

The installation should be discussed in detail with the foreman, set-up man, and operators immediately concerned. Procedure for gathering, recording, and plotting data should be explained along with the meaning of the upper and lower control limits.

After the initial application is followed through to a successful conclusion and further difficulty virtually eliminated, another trial installation should be made and again followed through to a successful conclusion. Success of these first trial installations will lead to rapid expansion of the program with every foreman requesting application of quality control procedures in their departments.

Many pilot or trial applications require changes or revisions of the quality control procedures. These revisions may be handled and controlled in pilot application with a minimum of confusion. Even the program itself can gain some prestige by correcting its faults before being released for plant-wide use. No single quality control plan is going to be perfect, therefore, one must expect a few revisions in the original plans.

<u>Departmental Indoctrination</u>

The expansion of a quality control program throughout the plant has to be done in steps, as such a comprehensive program could not be attempted without trained men. Care in selecting patrol inspectors is essential, as they must be accurate and thorough, must be able to work with and hold the respect of operators as well as supervisors, and must be able to develop an understanding and appreciation of the basic principles underlying statistical control methods. A course should be organized for those selected to do the actual patrol inspection and follow-up work. This course should include the basic principles underlying the use of control charts as well as the gathering, recording and charting of data for operations of the type performed. Since the average shop man or inspector neither knows enough basic mathematics, nor has used it sufficiently to become proficient in the calculations of averages and the conversions of fractions to percentage, it becomes apparent that some time has to be spent in review.

Each patrol inspector must not only be able to take accurate readings with measuring instruments, but must also be able to plot his findings on control charts. After compiling and recording all the information, it is necessary that the results be interpreted correctly so that the maximum efficiency may be obtainable through this control.

After the inspection and supervisory personnel becomes indoctrinated in the quality control techniques, the operator must be told and shown the if's, why's and how's about the program and quality control. The operator must be sold on the idea of quality as he controls the product leaving his machine. In many cases they will be used to their old methods of inspection and simply cannot understand why any new system is necessary.

From time to time it will be necessary to have the experienced patrol inspectors, supervisors and operators attend special classes to study new applications and different methods for gathering data, and to discuss interpretation of past and current charts.

Quality Assurance

The assurance of quality control is the reporting function that tells management how well the quality phase is being performed. The inspector, by accurate and complete reports of defects, can measure and record the level of manufacturing quality. Correct recording and the proper use and interpretation of these records often spell the difference between a controlled and an uncontrolled job. Interpretation of the specifications by the inspectors must be uniform in order to assume accurate reports. Poor training or a lack of complete training results in different concepts of defects, and consequently some inspectors find a wider variation of defects than others.

In order to obtain this quality control assurance it is quite necessary to insist that proper personnel be placed in those positions that control the discipline and maintenance of all quality control functions. No system, plan, or program can be any better than the personnel that directs or controls them.

Time Schedule for Program

The pilot installation usually decides whether or not the plan is ready to move into the shop. These installations always help to iron out mistakes and variations in the method and prevents overall mistakes from occurring later. After a decision is reached to apply quality control throughout the entire organization, actual plans should be formulated for extending the application to other departments or areas.

The actual start and sequence of the expansion program depends largely on what is needed most, or what phase of the industrial scheme is giving quality the most trouble. No matter where the installations start or end, the launching of the main program should be made according to a predetermined time schedule. This time schedule tells the sequence and time of the departmental installations. Comparison between actual time schedule and current standing denotes evidence of progress of the quality control program. When installation of the program lags for no apparent reason or reasons, more effort and co-ordination must be applied to bring the overall program back on schedule. Many quality control programs have failed because of the excessive time lag between initial pilot adoptions and final installation.

Summary

In formulating a Quality Control Program it is necessary to outline the ultimate objectives desired of the program. The plants needs should be carefully analyzed and the basic quality control program should be tailored around these requirements.

Before Quality Control can become effective, it must be sold to the complete organization. Top management must be quality minded and must transmit this attitude to the secondary management, to the foremen, and to the workers themselves. A sincere and continuous selling drive constantly building up the pride of good workmanship will develop an organization of quality-mindedness that will insure the quality of the manufactured product.

Two of the best ways of starting a quality program in a plant is to: (1) Install proper Tool and Gage Control System to insure accuracy during inspection, and (2) Stop receiving non-conformance parts from vendors by adequate Incoming Material Inspections. A pilot quality control plan introduces the new program slowly thereby allowing the operators, inspectors, foremen, etc., the opportunity to digest the new plan. Further expansions of the program will prove favorable with a successful pilot installation.

CHAPTER VII

APPLICATION OF QUALITY CONTROL

Quality Control Programs differ among companies because of the many types of operations which must be kept in control. Manufacturing organization, source of materials and quality level that must be maintained all tend to indicate the appropriate type of quality control program to be used. The quality control practices of many companies were surveyed and analyzed. The high spots of the practices are described in the following studies.

Johns-Manville Corporation

Johns-Manville Corporation within its seven divisions, manufactures a few hundred different lines of products. Quality Control within this company dates back to 1936. The Organization of Quality Control is based on a centralized staff function. The Director of Quality Control who reports to the Vice-President for Production, outlines the policies and methods to be followed by the entire quality control organization in the company. The Quality Control Managers, appointed for each division, reports to the Production Manager of the division, and on a functional basis, to the Director of Quality Control. Quality Control Supervisors report to the Quality Control Managers of his division. This set-up permits flexibility which the individual divisions require and retains an overall program for the entire company.

Johns-Manville applied statistical approach of quality control to raw materials, processes, and finished goods in an effort to maintain quality within the company. Various types of approaches were considered before a motion picture with suitable narration was selected as the most effective medium of putting the principles of quality control across to production managers, supervisors, inspectors, and production men. The motion picture concentrated on the problem and products of Johns-Manville was made in simple terms outlining the basic concepts for the use of statistics in quality control. The film is also used as a training tool for training inspectors and foremen.

The Director of Quality Control maintains a complete set of records for all quality applications. Also each Quality Control Manager keeps records of their respective divisions. All records are kept up to date with graphs, charts, and resumes. A Quality Control manual is maintained by each division and contains detailed description of what is to be done to insure proper control. These manuals are the law which govern the activities pertaining to manufacture of goods to the established standards of quality.

The Quality Control program at Johns-Manville has proved economical by reducing the production of off-specification materials and by effective savings of material, man hours, and rework.

S. K. F. Industries

S. K. F. Industries produce roller and ball bearings along with necessary housings for encasement. Statistical Quality Control was introduced in 1942. Formal quality control classes were started as a means of introduction to establish a clear understanding of the techniques of this new system. Gradually, however, these men were sold on the new quality control program. The successful operation of the entire program was not a job established overnight. Slowly, but steadily the system was put into operation. throughout the entire plant.

At S. K. F. the Quality Control Supervisor has complete charge of the quality control department. He reports directly to the Quality Control Manager who in turn reports to the General Factory Manager. The entire quality control program is directed by the Quality Control Supervisor and is nothing more than a series of practical applications of the quality control theory.

Raw Materials Control are maintained through formal sampling procedures. "In process" control is based on the use of acceptance sampling tables with an allowable Average Outgoing Quality Level (AOQL) of 2% or less. Finished product inspection is a 100% inspection function. The Quality Control Department makes a spot check on the finished bearings in stock to insure that production meets specification.

Quality Control at S. K. F. Industries has produced greater all-around efficiency through the reduction of scrap, inspections, and rework. The workers benefit also by receiving greater pay by producing better material with less rejects.

Alexander Smith and Sons Carpet Company

Alexander Smith and Sons Carpet Company is one of the largest carpet mills in the world. The mill can basically be divided into two carpet and rug mills and one yarn mill. The two carpet and rug mills produce directly for consumer use; and the yarn mill spins the wool yarn that is used in the rug divisions.

Quality Control is administered under the Research and Development Division. Prior to the establishing of this division, about seventeen years ago, the laboratory handled all the testing of purchased materials such as dyestuffs and scouring materials. As more and more actual research became necessary, management recognized the importance of the testing department function to the security of the company's future. The testing department established statistical methods of quality control for testing strength and weight of yarns, as well as dyeing, scouring and sizing operations.

The Quality Control function in textile industries usually lies within the research and development divisions. In testile industries, there is little or no waste nor is there any rework of substandard materials as there is in the metal working industries. In textile industries the quality function is conducted from the laboratory. In process tests and inspections serve only as guides for future production. Final inspection merely consists of the detection of visible defects. All material with visible defects is sold as seconds and only on very rare occasions is any production scrapped.

Alexander Smith and Sons applies quality control techniques to all incoming materials. Upon receipt of any material, personnel of the quality group actually take physical samples and perform the necessary inspections.

The inspectors assemble their data in the form of control charts which serves as a basis for future sampling as well as a manufacturing guide for making corrections to allow for variations in the raw materials. Monthly reports, sent to high level officials, concerning the incoming material inspection data reveals vendors supplying off-standard material and at the same time puts considerable pressure on the Purchasing group for obtaining accredited sources.

In process inspections and tests are aimed at controlling the process average and uniformity rather than accepting or rejecting. All quality control data and charts are used to set standards and to correct mistakes for future production runs. Final inspection actually checks the product appearance in relation to that of standard. Perfect products are segregated from the imperfect product and a tabulation is made of the causes of the imperfect products. Tabulation of the causes for imperfects are classified so that the departments responsible for the imperfects are familiar with the extent to which they cause imperfect material.

The Quality Control Program at Alexander Smith and Sons Carpet Company aims at the goal of standardizing textiles quality standards. Application of the Statistical Quality Control techniques provides an understandable method which indicates the current quality and also points out the necessary measures to be taken to improve the quality level in the future.

Weatherhead Company

The Weatherhead Company is a large manufacturer of screw machine parts for all types of customers. The number of parts manufactured by this company seem almost innumerable. Some parts are just plain individual pieces while other parts are assembled. Essentially, it is a large job shop specializing in high-speed screw machine production.

The Quality Control Program was started in the early part of 1948. Prior to this installation quality control techniques were tried and found very successful on several troublesome jobs. The Quality Control Department reports directly to the factory manager and operates in parallel to the inspection department. Quality Control confines its activities to analyzing the manufacturing process and controlling the quality of specific lines.

Before expanding the Quality Control Program within the shop, it was necessary to install a training program where carefully selected inspectors and inspection foremen were trained in the techniques of quality control. After adequate training these inspectors were ready to put Statistical Quality Control to work. At the same time all production foremen were given a series of lectures in Quality Control.

The Quality Control Department confined its initial program to one particular division and assigned the newly-trained quality control inspectors to this division.

Suitably equipped quality control stations were established for the use of the Quality Control Department.

Job shops present many problems that differ in many respects from those in a manufacturing process that makes the same product day after day. This fact is made more difficult when the plant is large and the operations are high speed.

One of the biggest problems confronting the job order shop is obtaining enough such groups upon which to establish quality control limits before the job runs out. In order to take care of short run jobs, the Weatherhead Company uses the frequency distribution analysis. After the operation has been approved by the first piece inspector, the quality control inspector would take the first fifty pieces from the machine and measure the quality characteristics involved. The results are tallied and the $\bar{x}$ and the standard deviation is calculated. This tally gives a rough picture of the distribution and the $\bar{x}$ and standard deviation help to decide whether or not the process is satisfactory. The same procedure, sample of fifty, is repeated at the end of the run, and again the distribution is checked against the tolerance. After the job is completed the control charts and data sheets are returned to the quality control department office. Here all data and charts are carefully examined and revisions in tools and methods are discussed if necessary. Quality limits are revised, accordingly, so that the next time the particular job is run the latest information is available to the quality control inspector. The same procedure is followed in cases where the fraction defective chart is the only practical control.

The Quality Control Program was expanded slowly by divisions with the gains consolidated as they progressed. Weatherhead Company experienced the following results from their Quality Control Program:

1. Reduction of Scrap.
2. Improvement in quality parts through use of Control Charts.
3. Method of determining the best tooling set-up.

General Electric

General Electric, makers of a wide assortment of appliances and diversefied products, looks on quality control as an essential part of its manufacturing operations. Quality Control at General Electric is basically an engineering function, therefore, it reports to Department Manager of Engineering. The division Quality Control Engineers, report functionally to the Department Engineer of Quality Control and operationally to the Division Manager and furnishes each with detailed monthly reports of

Quality Control activity.

Within the plant the control function is administrated by a quality control group that is supervised by the Quality Control Engineer. The group's function is to properly integrate the control functions into the manufacturing operations. This job includes setting up sampling tables, keeping control charts and designating control points. Actual operation of the quality control procedures is performed by the inspection department which either accepts or rejects the work according to the standards set up by the quality control group.

In order to avoid misunderstandings, the General Electric Company, whenever purchasing materials, furnishes the vendor with the quality requirements and quality level expected before the formal order is placed for the material. In some cases the vendor is requested to furnish evidence of his inspection in the form of a "Certificate of Quality". This allows reduced inspection to an honesty check. The purchasing department is constantly furnished with the performance and quality records of all its vendors, for the purpose of aiding the purchasing department in placing orders with vendors in the basis of quality as well as price.

At General Electric the quality of incoming material is controlled by single sampling, double sampling and control charts. The single and double sampling tables are based on the standard tables set up by Dodge and Romig. Whenever the vendor is requested to certify the quality of his product, incoming material inspection will not accept the material until such certification is received.

In process control of parts manufactured are carried out also by single and double sampling plans as well as control charts. Control charts are most effectively used when the characteristics being checked are variables. Each operation has its own operator's control sheet giving the instructions to the operator for inspecting and sampling his work. Operators seem to be quality-minded and by keeping these charts the operator knows the progress and quality of his work.

Most finished products go through a final functional test and them inspected 100% for visual defects. After this, a spot check of between 1% and 5% of the finished products are given a very extensive inspection and test. Results of all these tests are recorded and periodically tabulated and finally analyzed by upper management.

General Electric, through the use of Quality Control techniques, has lowered inspection cost and improved product quality during the manufacturing process. By adequate sampling and control techniques, parts are controlled at a satisfactory quality level during manufacturing, therefore, production errors found in the final product are reduced to those developed during assembly. Prior to the installation of the quality control program, it was necessary to adopt 100% inspection at many points during the manufacture as well as the finished product. Any parts in material frequently found to be defective are put through an intensive test to determine the cause. Any defects that cannot be found are transferred to engineering development for possible change in design to eliminate any uncontrollable defects. General Electric has obtained successful results from its Quality Control Program and claims it to be an essential part of its manufacturing operations.

CHAPTER VIII

Conclusion

Quality control, in its broadest sense, is the process of preventing the manufacturing of products below a desired standard. Modern quality control is the technique of following the trend and extent of deviation of a product or its parts from accepted standards during the process of manufacture, thus permitting corrections to be made before quality drops below desired limits. Quality control is a relatively new, but fast growing, tool of management that offers a scientific and low-cost method of discovering and correcting mechanical and human deviations during the production process. Final inspection is not eliminated but, when all steps from raw material to finishing are kept in control, it is quick, simple, and certain.

The company's size and type of its products determine whether the quality control function is handled by a separate department, by a sub-department, or by one man. The line of responsibility usually runs direct to top management or, in some cases, to the operating heads of the organization. Quality control cannot be reduced to a simple formula which, upon application to a business organization, immediately takes effect and produces a cheaper and consistently better product. Methods that are effective for one concern may prove harmful for another.

Although the fundamentals of almost all systems of quality control are based on the theory of mathematical probability, there are variations in their operation and presentation. Even in cases where end products are similar, the system of control may be entirely different.

Because many departments of a business organization are involved, considerable educational work must be undertaken in introducing the control program and in bringing about the co-ordination that is necessary to obtain satisfactory results. Companies usually orient their top management and unions before introducing the control methods to plant personnel.

The most widely used tools of statistical quality control are acceptance sampling, frequency distributions and control charts. Mathematical formulae based on the probability theory are used to set up sampling tables. Control charts showing averages and range of deviation of a given sample enable machine operators to know the quality of the work at frequent intervals.

Examination of existing quality programs in a number of plants, prove that although the basic application of the functions of quality control may vary from industry to industry, the results all tend to be similar; improved quality, savings of materials, rework, and man hours. Statistical quality control, by providing a preventative and corrective technique of stabilizing a process, has proved itself to be one of the best ways to make inspection and production profitable. It must be understood, however, that results are dependent on the skill and understanding of the operating personnel. A program is no better than its director. With reasonable guidance, any quality control program can produce results most favorable to top management.

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